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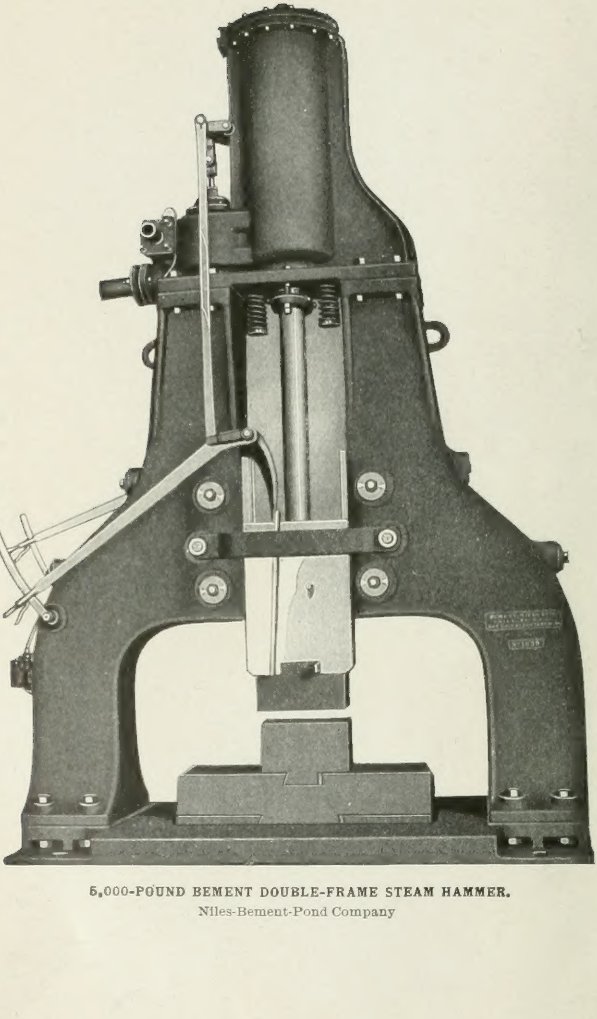

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost manufacturers and engineering firms, in making these volumes thoroughly representative of the best and latest practice in the design and construction of steam and gas engines, machine tools, and other classes of modern machinery; also for the valuable drawings and data, suggestions, criticisms, and other courtesies.

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Foreword

THE rapid advances made in recent years in the field of Mechanical Engineering, as seen in the evolution of improved types of machinery, new mechanical processes and methods, and even new materials of workmanship, have created a distinct necessity for an authoritative work of general reference embodying the accumulated results of modern experience and the latest approved practice. The Cyclopedia of Mechanical Engineering is designed to fill this acknowledged need.

¶ The aim of the publishers has been to create a work which, while adequate to meet all demands of the technically trained expert, will appeal equally to the self-taught practical man, who, as a result of the unavoidable conditions of his environment, may be denied the advantages of training at a resident technical school. The Cyclopedia not only covers the fundamentals that underlie all mechanical engineering, but places the reader in direct contact with the experience of teachers fresh from practical work, thus putting him abreast of the latest progress and furnishing him that adjustment to advanced modern needs and conditions which is a necessity even to the technical graduate.

¶ The Cyclopedia of Mechanical Engineering is based upon the method which the American School of Correspondence has developed and successfully used for many years in teaching the principles and practice of engineering in its different branches. It is a compilation of representative Instruction Books of the

School, and forms a simple, practical, concise, and convenient reference work for the shop, the library, the school, and the home.

¶ The success which the American School of Correspondence has attained as a factor in the machinery of modern technical and scientific education, is in itself the best possible guarantee for the present work. Therefore, while these volumes are a marked innovation in technical literature — representing, as they do, the best ideas and methods of a large number of *different* authors, each an acknowledged authority in his work — they are by no means an experiment, but are in fact based on what has proved itself to be the most successful method yet devised for the education of the busy workingman. They have been prepared only after the most careful study of modern needs as developed under the conditions of actual practice in the Machine Shop, the Engine Room, the Drafting Room, the Factory, etc. The formulæ of the higher mathematics have been avoided as far as possible, and every care exercised to elucidate the text by abundant and appropriate illustrations.

¶ Numerous examples for practice are inserted at intervals; these, with the test questions, help the reader to fix in mind the essential points, thus combining the advantages of a textbook with those of a reference work.

¶ Grateful acknowledgment is due the corps of editors and authors — engineers and designers of wide practical experience, and teachers of well-recognized ability — without whose co-operation this work would have been impossible.

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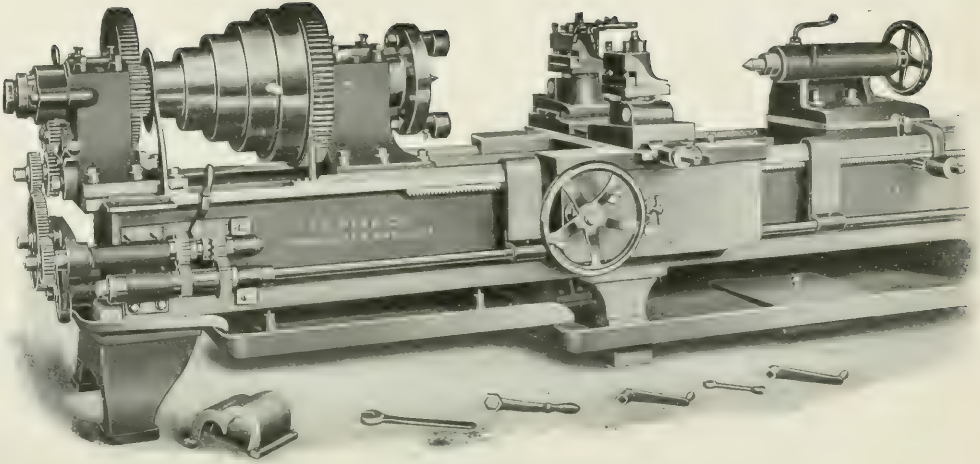

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MACHINE SHOP WORK.

PART I.

Machine shop work is usually understood to include all cold metal work in which a portion of the metal is removed to make the piece of the required shape and size either by power-driven or hand tools. However, there are some branches of cold metal work, such as sheet-iron work and coppersmithing, that are not included in machine shop work.

HAND-OPERATED TOOLS.

As the hand-operated tools are much simpler, and as the operations performed with them are in every case more typical, their description and use should precede that of power-driven tools. It should be clearly understood, however, that machine shop practice involves the use of both classes at the same time. Even hand tools are not used in the same order on different classes of work; it is, therefore, impossible to describe them in the order of use. Simplicity of construction and operation will be the guide for treatment in the following pages.

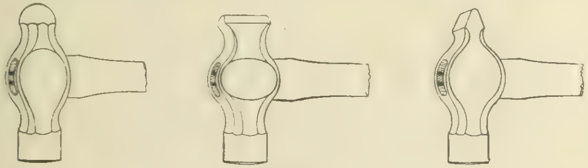


Fig. 1.

The machinist uses **hammers** of three shapes: ball pene, cross pene, and straight pene. See Fig. 1. The first named, the ball pene, is the most common; it varies in weight from four ounces to three pounds. The cross and straight pene hammers vary from four ounces to two pounds and are used principally in riveting. All hammers are made from a good grade of cast steel, hardened, and drawn to a blue color at the eye and a dark straw on the face and pene. The eye is elliptical in shape, and the handle is fastened by driving wedges, either wood or iron, into the end of the handle, thus spreading it to fill the eye. The handle is of hard wood, preferably hickory, and of a length suited to the weight of the hammerhead. When the handle is properly inserted, the axis of the head stands at right angles to the axis of the handle.

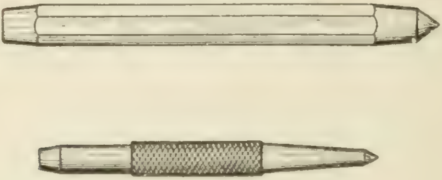


Fig. 2

Soft hammers are used for striking heavy blows where the steel hammer would bruise the metal or mar the surface. They are made of rawhide, copper, or Babbitt metal, and vary in weight from six ounces to six pounds. They are subject to rapid wear, but are indispensable in setting up and taking down machinery. Those of metal are so constructed that the soft metal can be recast in the handle.

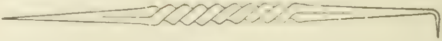


Fig. 3.

The *prick punch*, Fig. 2, is made of cast steel with a hardened conical point of about 60 degrees. It is about 3½ inches long and ¼ inch in diameter. It is used for making very small holes at intervals of about ½ inch on a line.

The **center punch**, also shown in Fig. 2, is made of the same general appearance as the prick punch, but is about 5 inches long, ½ inch in diameter, and has a point of about 90 degrees. The principal use is to make center holes marking the centers on the ends of pieces to be turned.

Both prick punches and center punches are usually made of hexagonal steel; but if round stock is used, the grip should be fluted or knurled to prevent slipping in the fingers.

The **scriber** or **scratch awl**, Fig. 3, is made in many forms, but consists essentially of a cast-steel rod about 8 inches long and $\frac{3}{16}$ inch in diameter, with a long, slender, hardened point at each end; frequently one point is bent at right angles to the shank. As the name indicates, this tool is used for marking lines on the surface of metal.

The **surface gauge** is used in laying out work for the bench, lathe, or planer. The ordinary form consists of a heavy base, an upright, and a scriber or scratch awl; the upright being firmly fastened to the base. In the universal gauge, the upright is pivoted at the base so that it may be used at any angle. In some forms the base is grooved in order that the gauge may be used on cylindrical work as well as on flat surfaces. See Fig. 4.

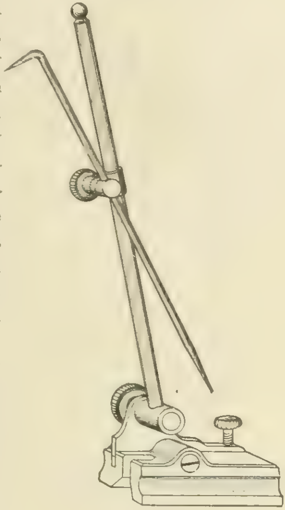


Fig. 4.

To use the gauge, the part of the work to be laid out must be prepared so that lines drawn on the surface will show distinctly. A rough or unfinished surface is covered with chalk, a finished or bright surface should be copper-plated by applying a thin coating of copper sulphate solution with a brush or a piece of waste. The work and gauge are then placed on a true surface and the scriber adjusted to the desired height. The line is drawn by moving the surface gauge along on the true surface, keeping the point in contact with the work. After scribing the lines, it is well to place light prick punch marks at frequent intervals along the lines, so that the position may be found if the chalk or copper sulphate becomes effaced.

The **straight edge** consists, in its simplest form, of a thin flat piece of steel, generally unhardened, with accurately finished straight edges. The very small sizes used in fine work are sometimes made with a hardened knife edge. A non-conducting handle is sometimes used with the small sizes to prevent distortion from the unequal heating due to handling. The short lengths used for ordinary shop purposes have one edge beveled, and are thick enough to avoid bending. See Fig. 5. The larger sizes, from three to ten feet or more in length, are usually made of cast iron with one finished edge. The metal is so distributed as to combine lightness with great rigidity, the tendency of the ends to drop being resisted by the truss-like form of the casting shown in Fig. 6. The flat form is used, in connection with the scriber, to draw accurate straight lines on plane surfaces. All styles are used to test the truth of plane sufaces by placing the straight edge on the surface to be tested in not less than the six positions shown in Fig. 7.

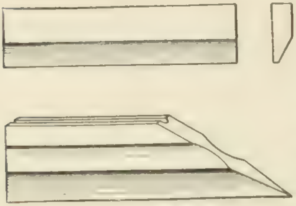


Fig. 5.

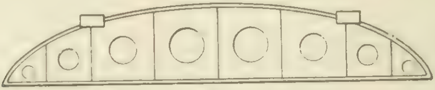


Fig. 6.

For drawing lines and laying off distances or curved surfaces, such as shafts, a combination of two straight edges, or a straight edge and a rule, is used. This is often called a *key seat rule* because its chief use is laying out keys on shafts. However, many machinists call it a "box-rule." It is usually made in one piece, although some manufacturers provide clamps by which the two separate pieces are held at right angles to one another. A more simple combination is shown in Fig. 8, the second scale being represented by two special clamps.

The simplest form of square, called the *flat square* (Fig. 9), is a combination of two straight edges at right angles. This is a useful form where the square is laid on the work. One blade is usually graduated on the inner edge, and the other on the outer edge. The flat square is not hardened.

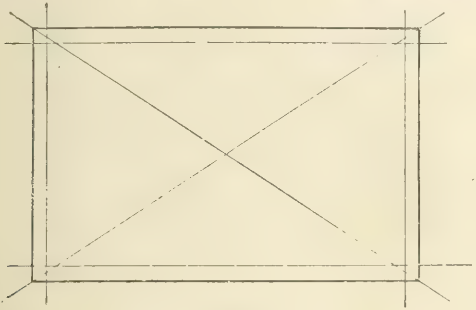


Fig. 7

The **try square,** shown in Fig. 10, consists of a beam and a blade at right angles. The beam is much thicker than the blade and somewhat shorter. Try squares are made both unhardened and hardened. The unhardened form has graduations on one edge, and is called the graduated try square. The hardened type always has a hardened blade, sometimes a hardened beam as well, and is not graduated.

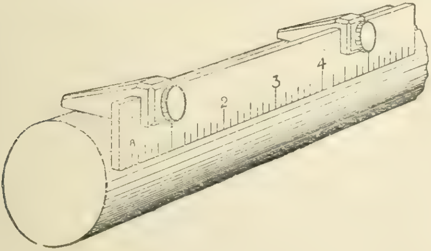


Fig. 8

The try square is used as a guide to draw lines at right angles to each other and to given surfaces; to erect and test perpendiculars to plane surfaces; to test the truth of a given surface at right angles to another surface; in short, it is used wherever an accurate measurement of 90° is required. When used for testing the relation of two surfaces, the beam is pressed closely against the correct surface, and the blade brought carefully down to the surface under consideration. This does not prove more than that a line at the particular point tested is or is not at right angles to the true surface. By using the blade as a straight edge parallel to the true surface, errors in that direction may be corrected and the surface be made plane.

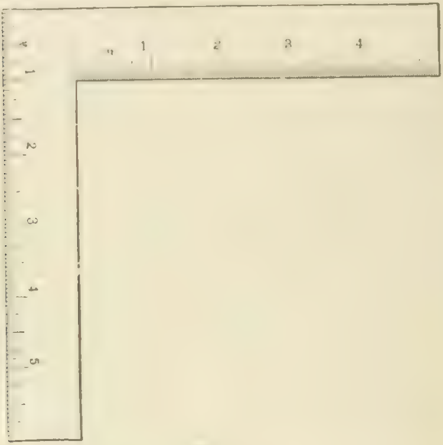


Fig. 9.

In many cases it is necessary to test the relation of lines and surfaces which are not at right angles to each other. For this purpose a **bevel** is used in which what corresponds to the blade of the square is made adjustable. Its construction is seen in Fig. 11, and its use is similar to that of the square.

The bevel can be adjusted only by direct application to lines or surfaces having the proper angular relation. It often happens that such adjustment is not feasible, and therefore a registering device, in the form of a graduated arc, is applied to the bevel, making what is known as a **protractor**, shown in Fig. 13. This tool can be used to find the angular relation in degrees or to produce that relation by setting to the proper point on the graduated arc.

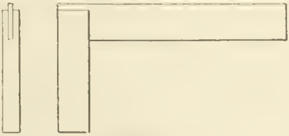


Fig. 10.

As the center of a circle is found at the intersection of any two diameters, an instrument for readily finding that point is a great convenience. In Fig. 12 is shown a combination of straight edge and square called a **center square**, which accomplishes this result. As one edge of the rule bisects the angle of the square, it is evident that a line drawn by that edge passes through the center of any circular piece to which the square is applied. Centering the ends of round bars or circular work of any kind is the principal use of this tool.

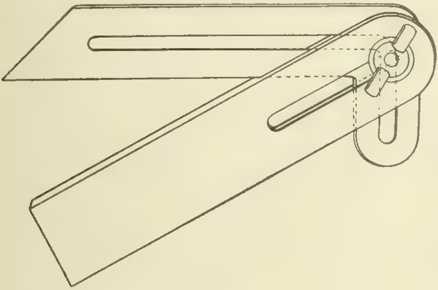


Fig. 11.

The center square, bevel, and protractor are furnished in a combination set as shown in Fig. 14. The ability to change the length of the blade is one of the great benefits of this construction.

MEASURING TOOLS

The testing tools thus far described are used for comparing the angular relation of lines and surfaces, and may be called tools for angular measurement. We now turn to the consideration of instruments for measuring distances and sizes, or tools for linear measurement.

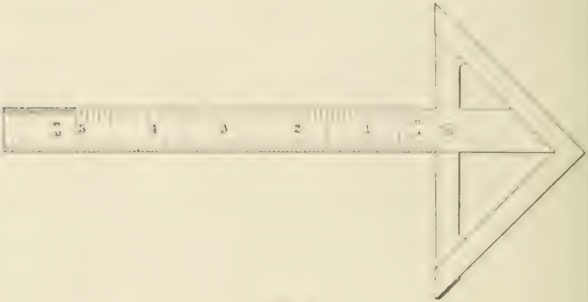


FIG. 12

The most common tool for *linear measurements*, and one which hardly requires description, is the so called carpenter's or two-foot rule. This is very convenient for the machinist in making measurements which are not required to be very accurate. For

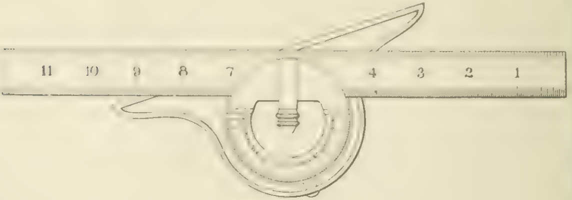


FIG. 13

work of greater refinement, the **standard steel scale** (Fig. 15) is used. This is in reality a divided or graduated straight edge and, as such, forms a part of several tools already described. The most common form of steel scale is flat, varying from one to forty-eight inches in length, and carefully hardened and ground. The graduations in the better class of scales are cut with a dividing engine, although the lines may be etched on the surface with a fair degree of accuracy. A thin and somewhat narrower form, called a flexible scale, is made in sizes from four to thirty-six inches. What are known as narrow scales are obtainable from four to thirty-six inches, and are of great convenience in certain cases. Besides these shapes, square scales are made in sizes from three to six inches in length, and the triangular form varies in length from three to twelve inches. Steel scales with the English system of graduation can be obtained with the inches divided in eighths, sixteenths, thirty-seconds, sixty-fourths; twelfths,

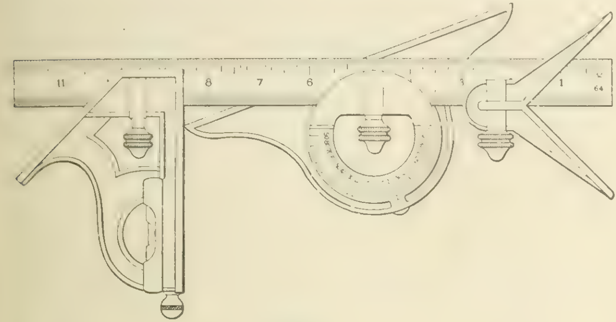


Fig. 14.

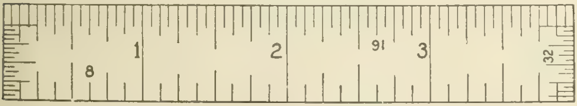


Fig. 15.

twenty-fourths; tenths, twentieths, fiftieths, and hundredths. Special scales are made with graduations especially adapted to such uses as gear blank sizing, etc.

The ends of flat rules are sometimes graduated, making what might be called a very short rule with a handle. Flat rules are sometimes graduated with Metric divisions as fine as one millimeter, and from five centimeters to one meter in length.

For transferring and comparing distances, **dividers** are commonly used. They are classified according to the style of joint and the length of the leg. The most simple joint is the friction and like all frictional devices, is hard to set accurately. Lock-joint dividers can be moved freely to approximately the right position, the joint locked, and the adjusting screw used for the final setting.

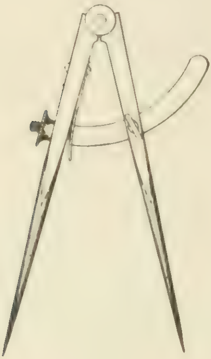


Fig. 16.

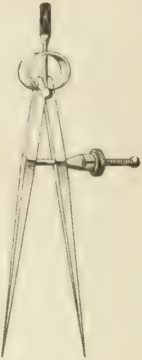


Fig. 17.

Wing dividers, Fig. 16, are of about the same construction as the lock joint, except that the fastening is made on the wing instead of at the pivot. The best of all forms has a spring adjustment as shown in Fig. 17. In this type, a spring tends to open the dividers, and the legs are closed against the spring by a nut working on a screw which is fastened to one leg and passes freely through the other. The length of dividers varies from two and one-half to ten inches. The distance to which dividers can be opened is generally about equal to the length of the leg. For distances above ten inches, *trammel points*, diagram, Fig. 18, are convenient. They consist of hardened steel points attached to metal sockets, and can be used on rods of any length. One point may have a spring adjustment, and in that case can be set in the same manner as a pair of wing dividers.

Next in importance to the dividers as an adjustable distance gauge, are the **calipers.** Instead of having straight legs with

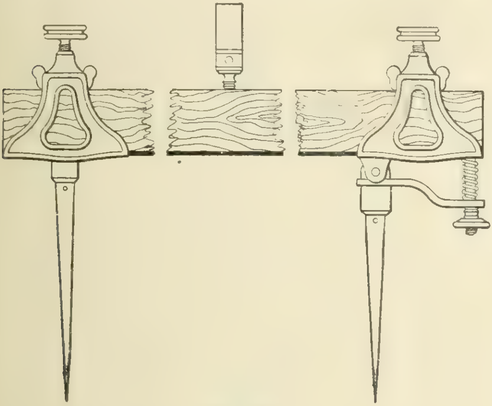


Fig. 18.

sharp points, caliper legs are bent and have blunt points. As distances are to be measured both outside and inside of solid bodies, we have outside and inside calipers. The legs of outside calipers have a large curvature so that the calipers may be passed over cylinders of their greatest capacity.

Inside calipers, Fig. 20, are more like dividers in general appearance, the ends being bent outward slightly and the points rounded. The same styles of joints used in dividers are used in calipers, and the size of calipers is also designated by the distance from the joint to the end of the leg. Spring calipers are made in sizes from two and one-half to eight inches, while the other styles vary up to twenty-four inches.

As it is sometimes necessary to make measurements behind shoulders and in chambered cavities, where the ordinary calipers could not be removed after setting, it is necessary to have calipers so arranged that they may be set, changed to clear the obstruction, and then reset accurately in the first position. This is accomplished by **transfer calipers**, shown in Fig. 19, in which one leg is temporarily fastened to a stub or false leg. After setting, this leg may be moved away from the stub, the calipers withdrawn, and the leg again placed in contact with the stub; the points will then be found to occupy the same position as when first set. Small curved legs may be used in place of points or trammels in calipering large objects.

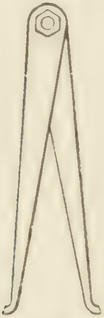


Fig. 20.

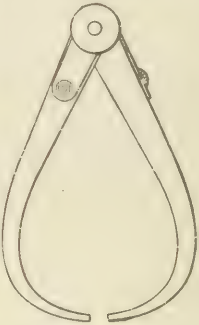


Fig. 19.

Both dividers and calipers are usually set by means of a scale. In setting dividers, place one point in a graduation of the scale, and move the other until it falls easily into another graduation which gives the required distance. Outside calipers are often set by placing one leg against the end of the scale and moving the other until it is opposite the middle of the graduation giving the required length. As the graduations are not mathematical lines, but have an appreciable width, this last precaution is one of great importance. Inside calipers are set by placing both the scale and caliper toe against a plane surface as shown in Fig. 21; the other toe is then set the same as the outside caliper.

Caliper legs are comparatively slender, are easily bent, and care must be taken in using them to see that the contact with the object being tested is very light. It is an easy matter to spring calipers of common sizes as much as one-sixteenth of an inch.

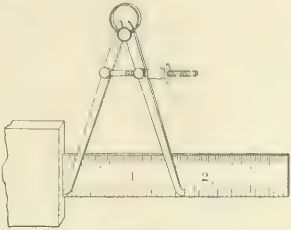


Fig 21

The **caliper square** is made by attaching a movable blade to the common square. In the ordinary forms it closely resembles a steel rule with two arms extending from it at right angles, one fixed near the end and the adjustable arm sliding along the scale with a clamping device for adjusting this movable arm. In order that the movable arm may be set accurately, caliper squares (Fig. 22), as at present constructed, have two clamps for the movable arm. The one carrying the thumb nut is to be first clamped in approximately the right position; the clamp on the movable arm being secured after the adjustment has been made by the nut. The sizes used vary from three inches up, and are limited only by the length of scales obtainable.

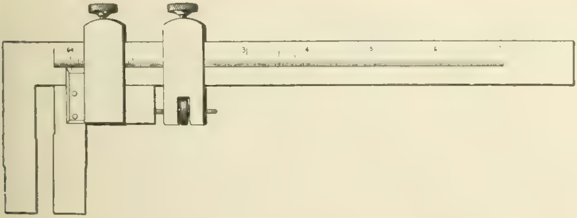


Fig. 22.

For measurements which are required to be more accurate than can be obtained by the preceding forms of calipering devices, the

micrometer caliper, Fig. 23, is used. The accuracy of its measurements is determined, not by direct setting to two lines, but by finely dividing the pitch of the measuring screw and furnishing means for reading these subdivisions. It is a registering as well as an indicating caliper, and thus serves the purpose of a common caliper in combination with a rule, but with a much greater degree of accuracy.

It consists, essentially, of a crescent-shaped frame carrying a hardened steel anvil B at one end and a nut of fine pitch at the other; the axis of the nut being at right angles to the face of the anvil. The outside of the nut, A, forms a projection beyond the crescent that is called the barrel. The measuring screw consists of a fine-pitched screw to fit the nut, combined with a measuring point C having a face parallel with that of the anvil. Firmly attached to the outer end of this screw, is a thimble D, fitting closely over the barrel; the edge of this thimble is beveled so that graduations placed on the edge come very close to the barrel. A reference line is drawn on the barrel parallel to its axis and graduated to represent the pitch of the screw. The chamfered edge of the thimble is so divided that the movement of one division past the reference line on the barrel indicates a movement of the measuring point of one thousandth of an inch. For example: if the pitch of the measuring screw is one hundredth of an inch, there should be ten divisions on the

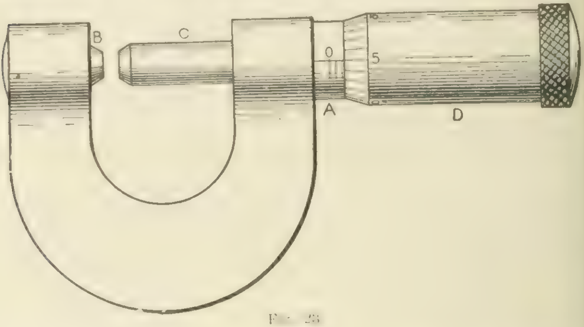


Fig. 23

thimble; if one fiftieth of an inch, twenty divisions; if one fortieth of an inch, twenty-five divisions; if one twenty-fifth of an inch, forty divisions. Measuring screws having a pitch of one fortieth of an inch are commonly used, and every fourth division on the barrel lengthened and numbered to indicate tenths of an inch as shown in Fig. 25.

In using the micrometer caliper, it should not be set at the size required and pushed over the work, but should be screwed down until the measuring point C and anvil B are in contact with the work; the size may then be read from the relation of the thimble to the reference line on the barrel. The proper degree of pressure to be applied to the screw is acquired only after extended practice, and some manufacturers place a friction device on the thimble so that undue pressure cannot be exerted.

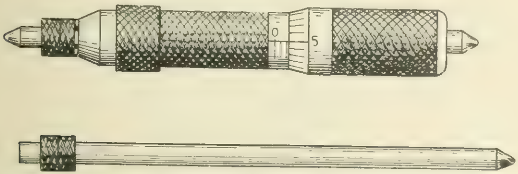


Fig. 24.

The micrometer caliper will not only indicate that the work is too large or too small, but will also show exactly the amount by which it differs from the desired measurement. This is a great improvement over the rigid form of calipers, and enables the workman to judge more accurately the progress of the work. This form of caliper is rapidly coming into favor in spite of its cost, and for this reason it has been described more at length than the common forms previously considered.

The range of motion of the measuring screw is usually limited to one inch. Various devices give the micrometer caliper a larger range of action. Micrometer calipers may now be purchased in combinations or sets giving a range from zero to twelve inches.

The application of the micrometer principle to inside measurements is not in general use, but is easy to arrange, and makes a very simple instrument, as shown in Fig. 24. It consists of an ordinary micrometer head, except that the outer end of the thimble carries a contact point, attached to a measuring rod which may be of any length. Two inches is about the shortest distance that can be measured with this device, but there is hardly any limit in length, as the rigidity of the rod is easily provided for. It is evident that such rigidity is harder to obtain in the curved shape necessary for outside measurement, and thus limits this form to about 12 inches, as above stated. The contact points in the outside type are parallel plane surfaces, and in the inside form are rounded points of small radius. Outside micrometers are pro-

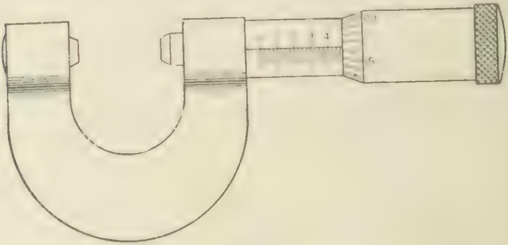
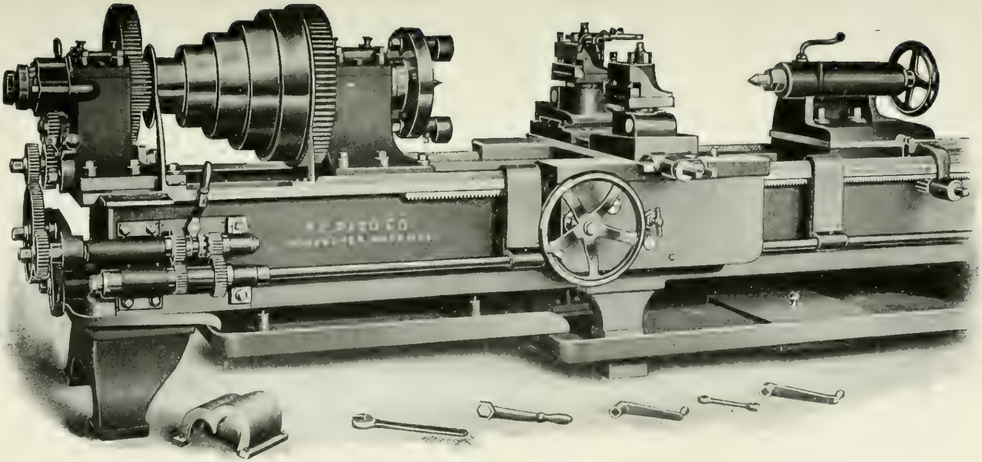


Fig. 25.

vided with contact points of varying forms for measuring paper, threads, walls of tubes, etc. The shapes for these purposes will not be shown, but may easily be imagined.

Reading the Micrometer. As stated above, the micrometer screw has 40 threads per inch and the thimble has 25 divisions on its circumference. The barrel is divided to correspond to th pitch of the screw with each fourth division numbered. In rea ing the indicated measurement, first note the highest number visi ble on the barrel, and call it hundreds of thousands or tenths. (I Fig. 25 it is 400 thousandths or .400.) Then read the sho divisions on the barrel, calling the first division 25 thousandth (.025), the second 50 thousandths (.050), and the third 75 tho sandths (.075). In this figure the third division is the last o visible. Now read the number indicated on the thimble; that i



24-INCH SPECIAL LATHE.
F. E. Reed Company.

the number that has passed the line running lengthwise. In the figure it is 16; or $16\frac{1}{2}$ if the reading is to be finer than thousandths. Add this reading to the readings of the short divisions, thus: $75 + 16\frac{1}{2} = 91\frac{1}{2}$; this is $.091\frac{1}{2}$. Adding the .400 to this we get $.491\frac{1}{2}$. This means that the distance from the anvil to the measuring-point is $\frac{491\frac{1}{2}}{1000}$ of an inch, or .4915 inch. If the micrometer caliper is a good one, we may be sure the distance is between .491 inch and .492 inch.

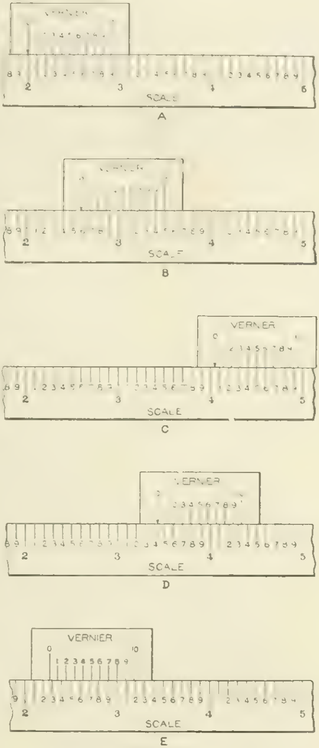


Fig. 26.

The Vernier. As has already been stated, the finest graduation that can be easily read on a steel rule by the naked eye, even after much practice, is one-hundredth of an inch. With the growing refinement in measurements, it was found necessary to obtain readings finer than this, and a method of subdivision, known from the name of the inventor, as the "Vernier," was adopted. The principle will first be explained. (See Fig. 26.)

Let two rules be so graduated that the true scale has each inch divided into ten equal parts, and the Vernier scale has ten divisions occupying the same space as nine of the divisions of the scale. It is evident that one of the divisions on the Vernier is equal to $\frac{9}{10}$ of one of those on the scale. Now, if the Vernier be moved to the right so that the graduations marked

1 shall coincide, the Vernier will have moved one tenth of a division on the scale, or one hundredth of an inch; when graduations numbered 5 coincide, the Vernier will have moved five hundredths of an inch; when lines marked 0 and 10 coincide, the Vernier will have moved nine hundredths of an inch; and when 10 on the Vernier comes opposite 10 on the scale, the Vernier will have moved ten hundredths of an inch, or the whole of one division on the scale. By this means the scale, although graduated only to tenths of an inch, may be accurately set at points whose positions are expressed in hundredths of an inch.

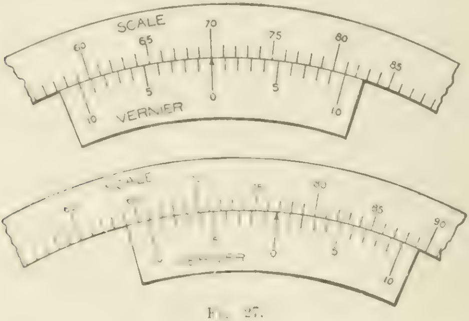


Fig. 27.

Let us consider Fig. 26. At A the Vernier is shown with the 0 in line with 2 on the scale; hence the reading is 2.000.

In B, the 0 of the Vernier has moved to the right beyond the division marked 5. The line 9 on the Vernier is in line with a line on the scale; hence the reading is 2.59.

In C, the zero of the Vernier has moved to the right still farther. The reading is evidently 4.05.

In D, the reading is 3.43.

In E, the reading is 2.28.

While arcs of small radius can be easily graduated into degrees, it is not possible to subdivide the degree without making the divisions confusing. By aid of the Vernier placed just above the true scale representing degrees, readings can be made with accuracy to one-tenth of a degree, or six minutes. The divisions of such a Vernier scale are shown in Fig. 27, and are also shown when set to read 76° 48′.

The most common application of the Vernier to linear measurements is found in the Vernier caliper square. The one shown in Fig. 28 reads to one-thousandth of an inch. Each inch of the true scale, or beam of the instrument, is divided into 40 parts (every fourth graduation being emphasized), while the Vernier, or sliding-scale, has 25 divisions, occupying the same space as 24 divisions on the true scale. By the reasoning used in connection with Fig. 26 the difference in length of one division on the Vernier, as compared with one of those on the true scale, is equal to one twenty-fifth of one fortieth or one thousandth of an inch. The caliper square shown in Fig. 28 is set at .279 inch. The scale is also shown enlarged in which the reading is 1.31 inch.

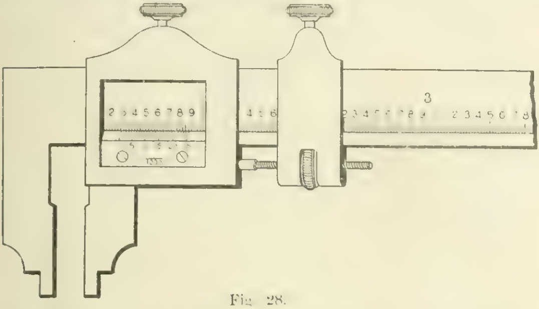


Fig. 28.

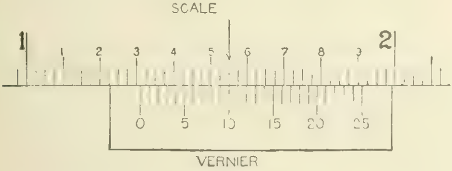


Fig. 28a.

By the use of the Vernier in connection with the micrometer caliper, readings are easily made to one ten-thousandth of an inch.

As shown in Fig. 29, lines are drawn on the barrel parallel to the reference line, making ten equal divisions occupying the same space as nine divisions on the thimble. Referring to Fig. 30, it will be seen that each division on the thimble may be accurately divided into ten parts, each indicating a difference in the position of the measuring point of one ten-thousandth of an inch. Rapid reading of the Vernier in any form can only be acquired by practice, but the following directions may be found helpful:

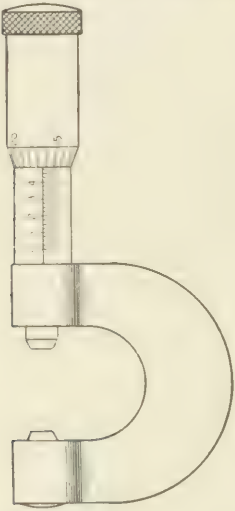


Fig. 28.

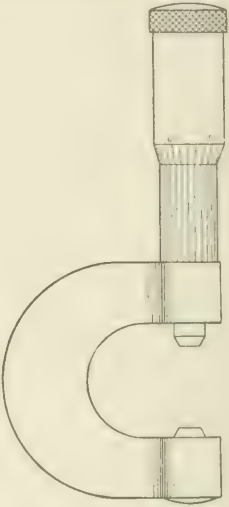


Fig. 29.

In Reading the Vernier, we must bear in mind the fact that each division on the Vernier is $\frac{9}{10}$ of one division on the scale, and that if line No. 1 on the Vernier is in line with any division of the scale the zero of the Vernier is $\frac{1}{10}$ of one division away from the graduation below it; if line No. 2 is in line, the zero is $\frac{2}{10}$ away from the graduation; if line No. 6 is in line, the zero is $\frac{6}{10}$ away.

Suppose the Vernier is in position on the scale and graduated as shown in Fig. 30. First read the highest division on the scale to the left of the zero on the Vernier. (69 is the division in the figure.) Then follow along the scale (to the right) until two graduations are found that are in line, as at 6 on the Vernier and 75 on the scale. Now, since one division on the Vernier means that the zero is $\frac{1}{10}$ of a division of the scale away, six divisions of the Vernier means that the zero is $\frac{6}{10}$ away; hence the zero of the Vernier is $\frac{6}{10}$ beyond the 69, and the reading is 69 and $\frac{6}{10}$ or 69.6.

Arcs of circles, such as are on surveyor's instruments, may be graduated to read to half degrees if the diameter is about 8 inches. Now, if we put on the circle a Vernier graduated so that we have 30 divisions equal to 29 divisions of the scale (arc), we can read 30ths of half degrees or *minutes.*

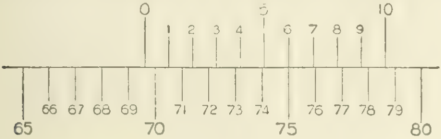


Fig. 30.

Vernier Micrometer. To get very accurate readings, a Vernier scale is placed on the barrel of the micrometer caliper. Let Fig. 29 represent the back side of the micrometer caliper shown in Fig. 25. The reading already obtained was .491 inch. Now turn the caliper over (Fig. 29), and, commencing at the right, count the graduations until one is reached that coincides or is in line with a graduation on the thimble. In doing this, call the first division zero, the second 1, the third 2, etc. The number of the division on the Vernier that is in line with the division on the thimble indicates the ten-thousandths above the regular micrometer reading. From Fig. 29 we see that the 5th line is the graduation which is in line with the division on the thimble which should be called 4, as explained above. Then the reading is .4914 instead of .4915, as we read it from the other side (the plain micrometer). With a good micrometer, we can be sure that the distance between the anvil and the point is more than .4913 and less than .4915.

The Retrograde Vernier. In addition to the direct Vernier, there is another form called the retrograde Vernier, which has 10 divisions on the Vernier and 11 on the scale. In this case the graduations on the Vernier must be reversed, as shown in Fig. 31.

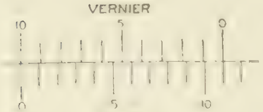


Fig. 31.

Calipers reading to ten-thousandths should not be commonly used when fine measurements are not required, because in an instrument of this class wear is perceptible and important which would be of comparatively little consequence in a caliper that reads only to thousandths.

In using the micrometer caliper for fine measurements, care should be taken in the handling of the instrument. Constant contact with the warmth of the hand will expand it sufficiently to make an error in the reading. The body should be held between the thumb and forefinger of one hand and the thimble turned with the other. It should be laid aside as soon as a reading has been made. It should never be laid upon a piece of cold iron, because the contraction due to chilling is likely to cause an error in the opposite direction from that which would be caused by the heat of the hand.

A

B

C

D

EXAMPLES FOR PRACTICE.

1. A micrometer caliper shows a reading of .463 ; how many times must the thimble be turned to produce a reading of .587? Assume 40 threads per inch. Ans. $4\frac{24}{25}$ times.

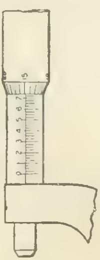
2. What are the readings of the Vernier micrometer calipers shown in Figs. A and B? Ans. .039.

3. State the readings of the micrometer calipers shown in Figs. C and D. Ans. .1546.

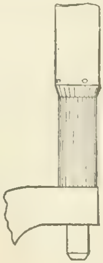
4. Give the readings of the Vernier micrometer calipers shown in Figs. E and F. Ans. .7398.

5. Sketch the front and back of a Vernier micrometer caliper when the reading is .6327.

6. What is the reading of the Vernier and scale when in position G? Ans. 6.36.



E



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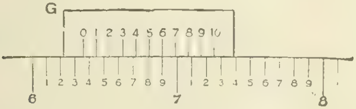


Fixed Gauges. While the adjustable gauges that have just been described are available for a large range of work, gauges of one dimension, or fixed gauges, are used to a considerable extent, especially in shops where work of a duplicate character is produced in large quantities. These may be used as standards to which adjustable gauges may be set, or used directly in connection with the work in the same manner as an adjustable gauge. The form of such gauges for comparisons of length is a steel rod with the ends carefully ground so that the distance required may be quickly and accurately determined. In one form the ends are parallel plane surfaces, and in another the ends are sections of a sphere of the same diameter as the length of the rod. Both these forms are illustrated in Fig. 32. Another form of gauge for the same purpose consists of hardened and ground steel disks, Fig. 33, to which calipers and similar tools may be set, and which may be used also to test the size of holes by direct application. For the latter purpose handles are provided by which the disks can be conveniently manipulated.

Plug and ring gauges, as shown in Fig. 34, furnish accurate and convenient standards for the production of duplicate parts of machines. The same result is attained by the caliper gauge shown in Fig. 35, which combines the two gauges in one piece. In this form the external gauge has parallel plane surfaces and the internal gauge is a section of a cylinder. In sizes above three inches, the caliper gauge is usually made in two parts, also shown in Fig. 35, making the tool easier to handle.

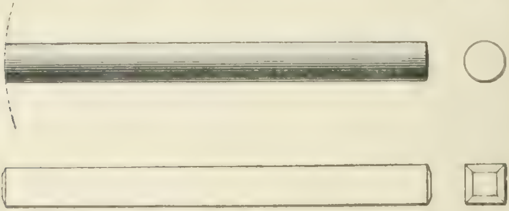


Fig. 32.

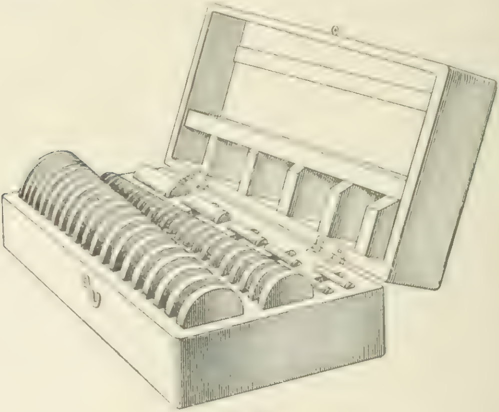


Fig. 33.

As is indicated by the cost of these gauges, the exact duplication of such exact sizes in quantities would mean a cost that would be prohibitive in machine construction. The limit of error in the standard gauges just described is never over one ten-thousandth of an inch at a standard temperature, which is usually taken as 70° F. Ordinary machine parts do not require such accuracy,

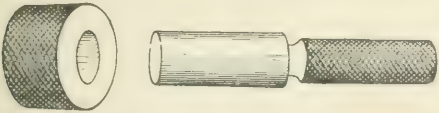


Fig. 34.

and it is usual to allow a limit of error which is in accordance with the class of work being produced.

For testing sizes and dimensions, both at the machine and in the inspection department, combination gauges, known as **limit gauges,** are employed. These are made both for external and

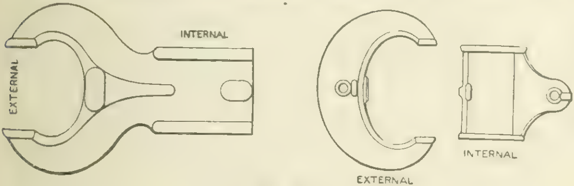


Fig. 35.

internal measurements. The external gauge shown in Fig. 36 is for testing pieces supposed to be .25 inch in diameter. As indicated by the figures on the gauge, the piece is allowed a variation of .0005 inch over, and .001 inch under the nominal size. The words "go on," and "not go on," stamped near the ends, indicate clearly how the gauge is used. This gauge is more conveniently arranged as shown in Fig. 37, in which the work must enter the first parallel opening, but must not pass through the second. In this form, one motion tests the piece for variation above and below the standard. Fig. 38 shows a limit gauge for holes, the end marked "go in" being required to pass into the hole, while the other end, marked "not go in," must not enter. An arrangement of the internal limit gauge similar to the external gauge of Fig. 37 is shown in Fig. 39, and has the same advantages.

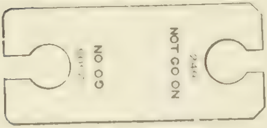


Fig. 36.

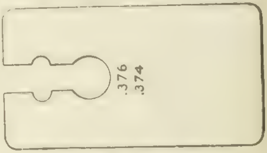


Fig. 37.

In some classes of work, no variation is allowed over the standard, and in others, no variation is allowed under the nominal size. The amount of variation allowed in any case is governed by the class of work and the intended use of the piece. As

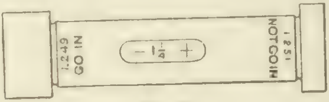


Fig. 38.

these allowances are not uniform, such gauges are made only to order.

For many years gauges of an entirely different character have been used in the measurement of wire, small rods, and sheet metal. The sizes have been designated, not by the diameter or any definite unit, but by a number or letter in a purely arbitrary manner. Even in the same gauge, the sizes do not advance in any regular order. The matter is still further complicated by the fact that in one gauge large numbers indicate large sizes, while in another, the smaller numbers mark the large diameters. Another source of annoyance lies in the fact that such gauges are cheaply made and cannot be relied upon to be duplicates of one another. These gauges were the natural result of the recognition by large manufacturers of the necessity of standards by which to grade their products. Hence we have such gauges as the Brown and Sharpe, Birmingham or Stubs, Washburn and Moen, United States standard, Morse Twist Drill Co., and many others. As a step in the right direction, a decimal gauge has recently been adopted, in which the sizes are indicated by numbers which represent the diameters in thousandths of an inch. Most of these gauges had their origin in days when refined measurements were not common, but since the use of the micrometer caliper has become almost universal, there seems to be no good reason why all sizes should not be expressed in thousandths of an inch, thus avoiding all the troubles incident to the use of the arbitrary gauges.

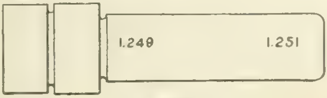


Fig. 39.

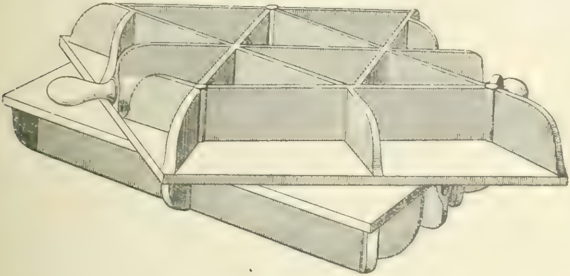


Fig. 40.

For the production of accurate plane surfaces the use of the straight edge is not sufficient. Such surfaces should be compared with standard surfaces called surface plates, Fig. 40. A surface plate is a cast-iron plate strongly ribbed on the back to prevent distortion, and supported on three points to insure a uniform base. The production and use will be described under the head of "Scraping." They may be had in sizes varying from 3 inches by 4 inches to 36 inches by 72 inches.

The machinist's **bench** at which hand work is ordinarily performed should be of substantial character, about two feet ten inches from the floor and two feet six inches wide (see Fig. 41). For the sake of economy it is usual to have a two and one-half or three inch plank at the front to which the vises are fastened and on which all the heavy work is done, while the rear of the bench is made from one-inch stuff. Maple and birch are preferred as materials for a bench, although ash makes a very good substitute.

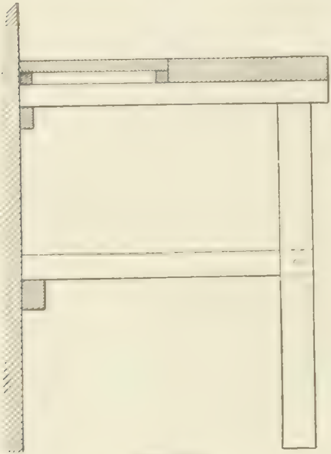


Fig. 41.

In order that work may be held rigidly for the performance of hand operations, the machinist uses what is termed a *vise*. They are made in a great variety of forms and sizes, but all consist essentially of a fixed jaw, a movable jaw, a screw, a nut fastened to the fixed jaw, and a handle by which the screw is turned in the nut and the movable jaw brought into position. The sectional view, Fig. 42, shows these parts clearly and also a device, present in some form in all vises, by which the movable jaw is separated from the fixed jaw when the screw is backed out in the nut.

In the machinist's vise, both jaws are made of cast iron with removable faces of cast steel. These may be checkered to provide a firm grip for heavy work, or may be smooth to avoid the marking the surface of the plate operated upon. When holding soft metal, even the smooth steel jaws would mar the surface; and in such cases it is customary to use false jaws of brass or Babbitt metal, or to fasten leather or paper directly to the steel jaws. The screw and handle are made from steel and the nut from malleable iron.

The common method of fastening a vise to the bench is by means of the fixed base shown in Fig. 42, although a swivel base such as is shown in Fig. 43 is preferable. The vise shown in Fig. 43 has a swivel jaw also which enables it to hold tapered work securely. This swivel jaw is provided with a locking-pin which fixes the jaws in a parallel position. The height of the vise from the floor depends somewhat on the class of work to be performed, but a general rule is to have the top of the jaws about one and one-half inches below the point of the elbow when standing erect beside the vise.

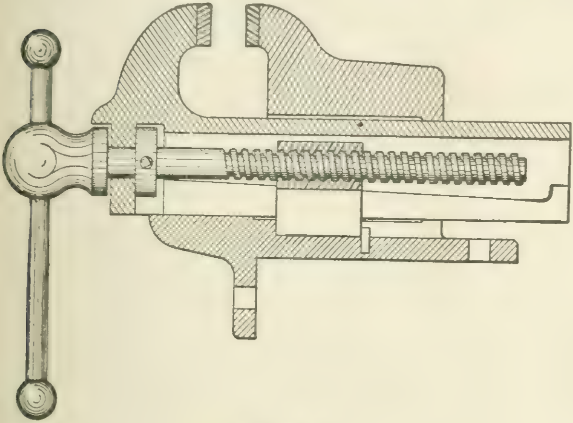


Fig. 42.

CUTTING TOOLS.

The simplest form of metal-cutting tool is the chisel. The several types in common use are shown in Fig. 44. The **flat chisel** is used for snagging castings, for chipping surfaces having less width than the edge of the chisel, and for all general chipping operations. It is the form most commonly used, and is often called the cold chisel. Generally it has a cutting edge about an eighth of an inch wider than the stock from which it is forged. The **cape chisel** is used for cutting key ways, channels, etc., and also for breaking up surfaces too wide to chip with the flat chisel alone. Channels are driven across such a surface, leaving raised portions or "lands" to be removed by the flat chisel. The cutting edge of this chisel is usually one-eighth of an inch narrower than the shank, and the part just in the rear of the cutting edge is made thin enough to avoid binding in the

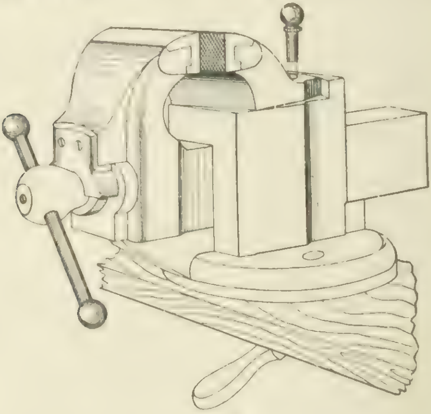


Fig. 43

slot. As this weakens the chisel, it is made comparatively thick in the plane at right angles to the cutting edge.

The **diamond point** chisel is made by drawing out the end of the stock to about $\frac{[illegible]}{16}$ inch square, and grinding the end at an angle with the axis of the chisel, leaving a diamond-shaped point. It is used for drawing holes, making oil grooves, and cutting holes in flat plates.

The **small round-nosed** chisel is cylindrical in section near the cutting end, the edge being ground at an angle of 60° with the axis of the chisel. When used to "draw" the starting of drilled holes to bring them concentric with the drilling circles they are called **center chisels.** This form is also used fo cutting channels such as oil grooves and similar work. The larger sizes of round-nosed chisels are of the general shape of the cape chisel with one edge rounded, making a convex cutting edge. Large round bottomed channels and all concave surfaces are the proper work of the round-nosed chisel.

All the accompanying forms should be made from a good grade of tool steel, carefully forged, hardened, and tempered to a purple color. The stock generally used is octagonal, and the chisels for heavy work are about eight inches long and three-quarters of an inch in diameter.

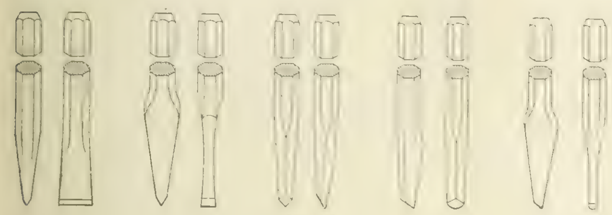


Fig. 14.

The two bevels forming the cutting edge of a chisel should make with each other as small an angle as is possible without leaving the cutting edge weak. If the angle is too small, the chisel will soon become dull, while if large, more force will be required to drive it. The best angle for cutting cast iron, all things considered, is about 70°, while for wrought iron and mild steel a slightly smaller angle, say 60°, will be better. When there are two bevels, they should be alike in width, and form equal angles with the center line of the chisel. Small round-nosed chisels and some slotting chisels are ground one-sided, that is, with but one bevel like a wood chisel. The angle between the surfaces which form the cutting edge should be the same, whether these surfaces are both bevels, or one a bevel and the other the straight side of the chisel. In a one-sided chisel, therefore, the angle that the bevel forms with the center line of the chisel should be twice as large as in one having two bevels.

To cut well, chisels should be sharp, and therefore should be ground at once when they become dull. This may be done on an emery or carborundum wheel, not finer than No. 60, care being taken to avoid heating, which draws the temper, and spoils the tool.

Chipping is a term applied to the removal of metal with the cold chisel and hammer. The degree of accuracy required varies. The piece is held in a vise, and the method of working is to grasp the chisel firmly with the left hand, holding the cutting edge to the work, and striking the head of the chisel with the hammer, keeping the eyes on the edge of the chisel to watch the progress of the work (see Fig. 45). The lower side or bevel of the chisel is the guiding surface, and is held at a very slight angle with the finished portion of the work, the cutting edge only touching. Raising or lowering the shank of the chisel increases or decreases the inclination of the guiding bevel, and causes the chisel to take a heavier or lighter cut. If the hand is carried too low, the chisel will run out before the end of the cut; while if the hand is raised too high, the progress will be slow, owing to the resistance offered by the metal to separation. The depth of the cut taken with a cold chisel should never be more than an eighth of an inch.

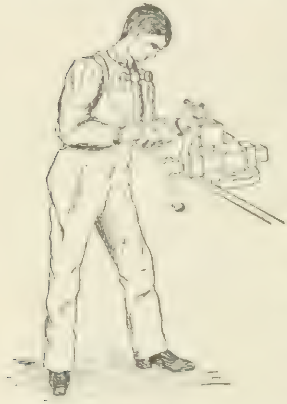
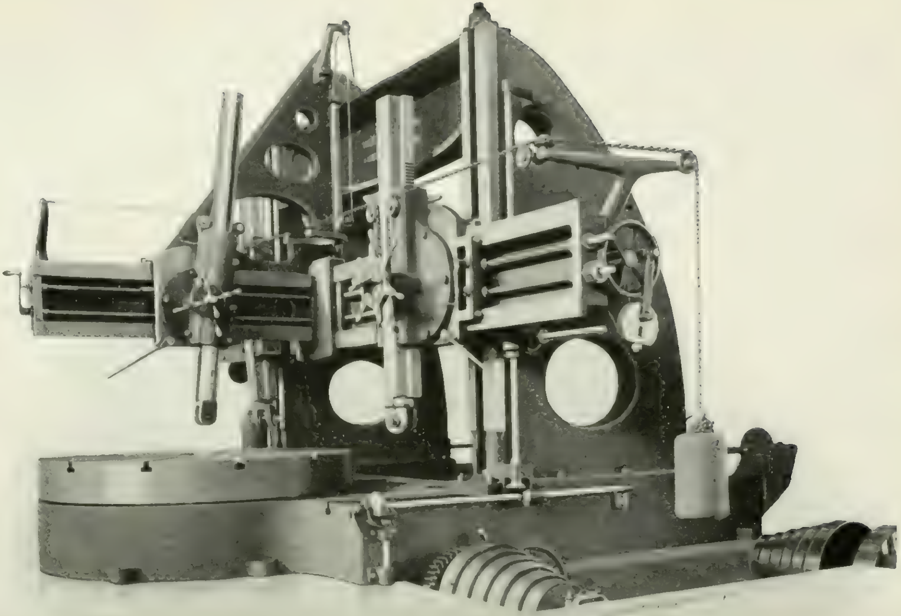


Fig. 45.

When chipping wrought iron or steel, a piece of waste saturated with oil should be kept on the bench, and the edge of the chisel frequently thrust into it. This lubricates the surfaces in contact and preserves the cutting edge of the chisel. While lines are used as guides in chipping operations, it is never advisable to bring the surfaces too near them with the chisel: sufficient stock must be left so that the surfaces may be finished with a file. This



BORING AND TURNING MILL.
Betts Machine Company.

is especially to be observed in chipping key ways with a cape chisel; an ample margin for filing should be left, both on the sides and on the bottom.

The **file** differs from the chisel in having a large number of cutting points instead of one cutting edge, and in being driven directly by the hand instead of by the hammer. As hand power only is used, it is evident that the amount of metal removed at one stroke will be small, and the amount removed by a single tooth will be exceedingly small.

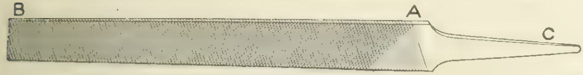


Fig. 46.

Files are made from cast or crucible steel, and in manufacture pass through the successive processes of forging, annealing, grinding, cutting, hardening, and tempering. They have three distinguishing features, viz., length, kind or name, and cut or coarseness of teeth. Length is measured from the heel A to the point B, Fig. 46; the tang C not being included. These lengths vary from three inches to twenty inches.

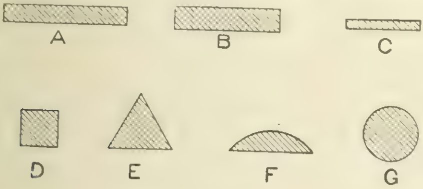


Fig. 47.

There are many kinds manufactured, those in common use being the flat (A), hand (B), warding (C), square (D), three square or triangular (E), half round (F), and round (G), sections of which are shown in Fig. 47.

The cut of files is in two styles, single and double; and each style has several grades of coarseness, viz., coarse, bastard, second-cut, smooth, and dead smooth. The last two grades are sometimes called fine and superfine. As is shown in Fig. 48, the coarseness of each style varies with the length — the longer the file the coarser the cut.

If the cutting surface of a file were perfectly flat, the number of teeth or cutting points engaged with the work would depend on the width of the file and the width of the piece being filed. To force as many cutting points as would be contained in such a large area deeply enough into the metal to enable each to remove its share of the stock, would be beyond the power of the man pushing the file. To avoid this necessity for great pressure, files are usually "bellied" or made slightly convex in the direction of their length, so that, theoretically, the file and the work are in contact only on a line as long as the width of the file. This enables the file to be forced into the metal sufficiently for the teeth to bite, and thus avoids dulling the teeth, which always occurs when the file is allowed to glide over the work without sufficient cutting.

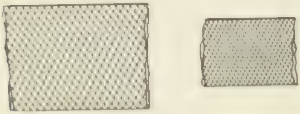


Fig. 48.

This convexity of files also serves another purpose. The pressure applied to the file to make it bite bends the file more or less (see Fig. 49), and if the file in its natural state were perfectly flat, when cutting it would be concave; and this would prevent the production of a flat surface. It would cut away at the edges of the work and leave a convex surface. Such files might, however, be used on convex surfaces.

Work for filing is usually held in a vise such as has already been described, and under ordinary circumstances the surface of the work should be about the height of the elbow. For fine work with small files, where close observation is of more importance than pressure on the file, the work should be higher than this, the height increasing with the refinement of the work. On the other hand, for very heavy filing, where great pressure is absolutely necessary, the work should be several inches below the point of the elbow, so that the weight of the body may be used to good advantage, and also because the workman naturally stoops a little when exerting great pressure on the file.

The handles commonly attached to files are made of wood and are made to fit the hollow of the hand. They are driven onto the tang of the file; a ferrule on the handle preventing it from splitting. Care should be taken to have the axis of the handle parallel with the file. A good way to prepare the handle for the tang is to heat the tang to a dull red, the file proper being kept cool by a piece of wet waste, and the hole in the handle burned out until the tang is almost in the position it is designed to finally occupy. After cooling the tang, very little driving will be required to securely fasten the handle to the file.

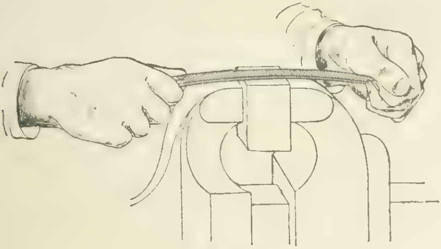


Fig. 49.

When filing surfaces of such size that the handle as ordinarily applied would interfere with the use of the file, the tang may be bent up to an angle so that the handle will clear the surface. Various forms of holders are used for filing under these circumstances; the simplest forms being shown in Fig. 50.

The correct position for filing is about as follows: feet about eight inches apart and at right angles, the left foot being in line with the file; stand back from the vise so that the body may follow the file slightly; grasp the file handle with the right hand, fingers below, thumb on top of the handle; for coarse filing, place the ball of the thumb of the left hand on the point of the file; for fine filing grasp the point of the file with the thumb and forefinger of the left hand. See Fig. 51. When holding the file in one hand, as is often done in light work, the forefinger should be on top of the file pointing in the direction of its length, as is shown in Fig. 52. This allows free movement of the hand and wrist, pressure being applied principally by the forefinger.

As file teeth or cutting edges point toward the end of the file, it is evident that the file can cut only when moving in a forward direction. On the return stroke, the pressure should be relieved; otherwise the teeth will be dulled when drawn back over the surface.

The kind of metal being worked determines in a great measure the character of the file to be used. Cast iron, especially if the scale has not been previously removed, is particularly hard on a new file, as the glassy character of the scale tends to dull the cutting edges. New files should never be used on such a surface. It is found that on tool steel, and hard materials generally, a second-cut file is better than the bastard. This is because if pressure enough is exerted to cause the coarse teeth of the bastard to bite into the work, the teeth, being comparatively long, are very likely to be broken off. In the second-cut file, the teeth are shorter and present more cutting points in a given area; thus preventing excessive duty being imposed on a few teeth.

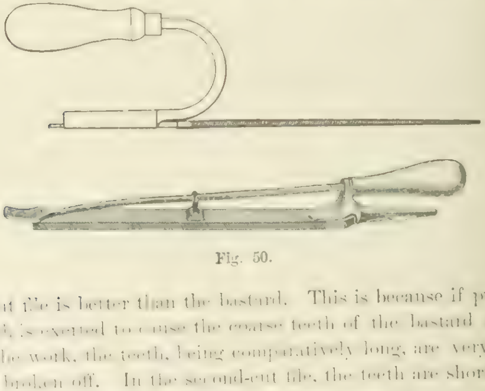


Fig. 50.

Softer metals, such as brass and bronze, allow the use of the coarser grades.

The particles of metal removed by a file frequently remain in the teeth and diminish their cutting qualities. In the case of hard metals these particles, or "pins," often scratch the work. It is necessary, therefore, that files be frequently cleaned. This may be done in a measure by striking the edge of the file lightly against the bench or vise, but it is more effectually performed by using a stiff brush or a piece of card clothing (Fig. 53). In the finest grades of files, a thin piece of wood or sheet brass may be drawn across the surface of the file as shown in Fig. 54, and the filings are removed by the points extending into the file teeth.

When filing cast iron, neither the file nor the work should be allowed to become greasy, as this tends to make the file slide without cutting. In filing steel, however, if the file be oiled or filled with chalk, the pinning of the file is prevented in a large degree, and frequent use of the card or brush is not necessary.

What is known as drawfiling is done by grasping the file at each end and moving it sidewise across the work. (See Fig. 55.) The amount of stock removed by this process is usually very small, the object being to lay the file-marks parallel to the length of the work. Single-cut files are better than double-cut for this purpose, being less likely to scratch the work. The remarks concerning cleaning, oiling, and chalking apply both to cross-filing and draw-filing.

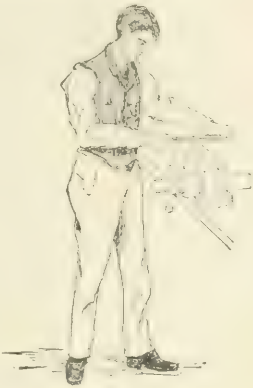


Fig. 51.

No matter how carefully filing is done, it does not leave a surface that is pleasing to the eye, the file-marks are more or less irregular and the whole surface is dull. Exposed parts of machines which are not painted are usually polished. Polishing

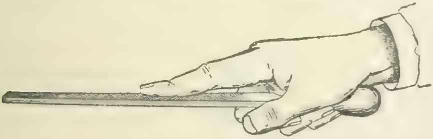


Fig. 52

does not improve the surface, but simply brightens it and renders it more attractive. As a rule, a polished surface is not a true surface, no care being taken to maintain its truth. In ordinary machine work polishing is usually done by abrasives, such as emery, corundum, and carborundum, while rouge, crocus, rottenstone, and tripoli are used on fine work, especially on brass and

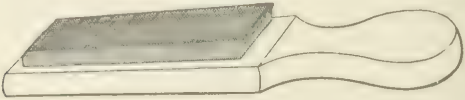


Fig. 53.

composition. Emery, for example, is crushed and sorted into grades varying from No. 8 to flour, the number of the grade indicating the number of meshes per inch in the sieve used in sorting. These grades sometimes bear arbitrary designations, No. 1 indicating a coarse grade and No. 0, 00, 000, 0000 showing the finer grades. These powders are sometimes mixed with oil and applied directly to the work by wooden blocks or clamps; but

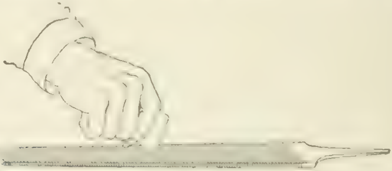


Fig. 54.

the more common method is to use what is known as emery cloth, the grains being glued to a strong cloth backing. The finer grades are used on paper in the same manner.

Emery cloth is used in many ways; it may be wrapped around a file; folded or tacked to a block of wood; glued to wooden sticks about 15 inches x 1½ inches x ½ inch, fastened around rollers for internal curves, or glued to wooden or steel disks and rotated in a lathe or special machine. In all cases the object is to grind down the surface, using a sufficient number of grades of cloth to produce the degree of polish desired. The marks are laid parallel to each other, making what is known as a "grain." When the process is to be carried to such an extent that no grain is to be visible, the finer polishing agents are used, usually applied with a cloth wheel or "lap." Old cloth does finer work than new, and oil on the cloth will make a finer cut.

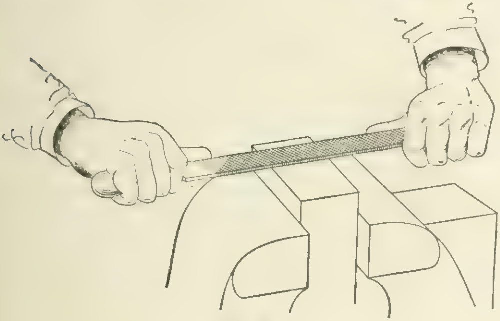


Fig. 55.

Scraping. When two flat or curved surfaces are to be worked together, and complete contact over the whole or both is desired, they are scraped. Scraping removes less metal than filing, and also enables the workman to confine the removal to limited areas. The scraper should be made from a very close-grained tool steel, and is nearly two feet long exclusive of the handle. The general shape is shown in Fig. 56. The cutting edge is about $\frac{3}{32}$ of an inch thick and $1\frac{1}{2}$ inches wide. It is ground on an emery wheel and grindstone, and carefully oilstoned, leaving the cutting edge as straight as possible. Scrapers are sometimes made from old files, the teeth being ground off and the end drawn out wide and thin. Sometimes the end is bent at right angles to the shank, as shown in Fig. 57. The cutting done by scrapers should be perfectly smooth and free from scratches.

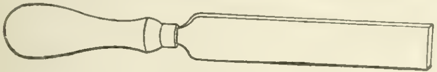


Fig. 56.

In using the surface plate as a test for the truth of a plane, such as a valve or its seat, the plate is covered with a very thin coating of red lead and then rubbed over the valve or seat. The latter should have previously been finished as smoothly as possible. The spots where the red lead shows contact are scraped off, and the process continued until contact over the entire surface is obtained. During the last part of the operation alcohol should be used instead of red lead, as it leaves clean bright spots to indicate where the scraper must be applied. Small pieces of work are rubbed over the surface plate, and in any case care should be taken to distribute the wear uniformly over the plate in order to prolong the truth of the plane. The scraper for concave surfaces, such as boxes, is of the general shape of a half-round file without teeth. In such cases, the shaft to be used takes the place of a surface plate. The method of holding and using such a scraper is shown in Fig. 58.

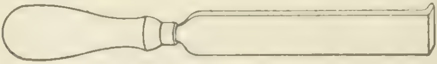


Fig. 57.

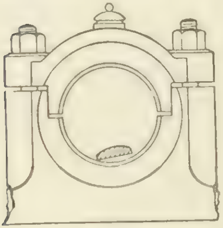


Fig. 58.

Scraping is sometimes done as a matter of finish, and not for the purpose of getting an accurate surface. Therefore, a scraped surface does not always indicate accuracy. Many machine parts are more cheaply finished by scraping than by polishing.

DRILLS.

Drills are of two general classes, the flat and the twist. A **flat** drill of a common type is shown in Fig 59. The angle between the two cutting edges should be about 110°. These drills are usually made from round tool steel drawn out wide and thin, as shown; the undressed end being used for holding. The flat drill is usually made in the shop where it is to be used. Its low first cost is the principal reason for its existence.

Flat drills made from thin flat stock are used in connection with a slotted rest to start and drill holes in the lathe without previous centering. They are called **chuck-drills**. The end of the shank of the drill is provided with a center hole to receive the dead center of the machine. The drill and rest are shown in Fig. 60.

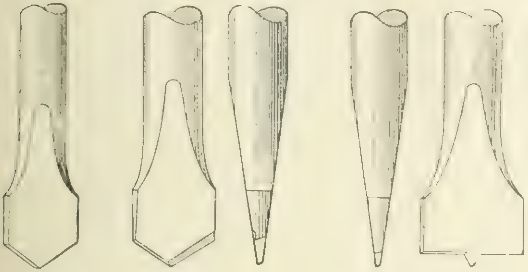


Fig. 59.

The simplest form of **twist drill** is cylindrical throughout its entire length, as shown in Fig. 61, and has two spiral flutes which at the end serve to form the cutting lips, and which also serve to carry the chips from the hole. The included angle of the lips is 118°. This form of drill will work more accurately than the flat drill, as the cylindrical portion serves as a guide to keep the cutting lips in their proper position. The edge being somewhat hooking, removes the metal by a cutting instead

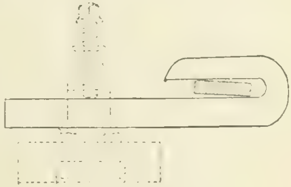


Fig. 60.

of a scraping action as in the flat drill. This form of drill cannot only be fed faster, but can be forced into the work with less power, as it has a tendency, especially noticeable in soft metals, to feed itself into the work. Straight shank twist drills are made from .0135 inch to $2\frac{1}{2}$ inches in diameter; the smaller sizes are sold in sets designated by numbers (1 to 80), letters (A to Z) or fractional sizes ($\frac{1}{2}$ inch to $\frac{1}{16}$ inch).

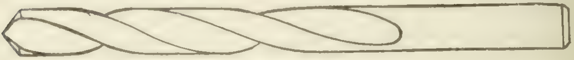


Fig. 61.

The *taper-shank twist drill* is shown in Fig. 62. It consists of a body A, which is fluted and does the actual work, and a taper shank B, by which it is held. This taper fits accurately into the spindle or chuck of the drill press. At the end there is a tongue C, which slips into the key way in the spindle or chuck. As this surface is flat, it serves as a bearing by which the drill is driven. This relieves the tapered portion from the stress of driving by frictional resistance alone. For small drills this frictional resistance is sufficient, but for larger sizes it will not do at all. If for any reason the tongue should become broken, no dependence should be placed upon the frictional resistance of the taper shank to drive the drill. The drill will slip and wear the socket, which will become enlarged and make a misfit for other drills

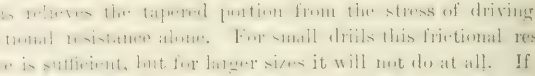
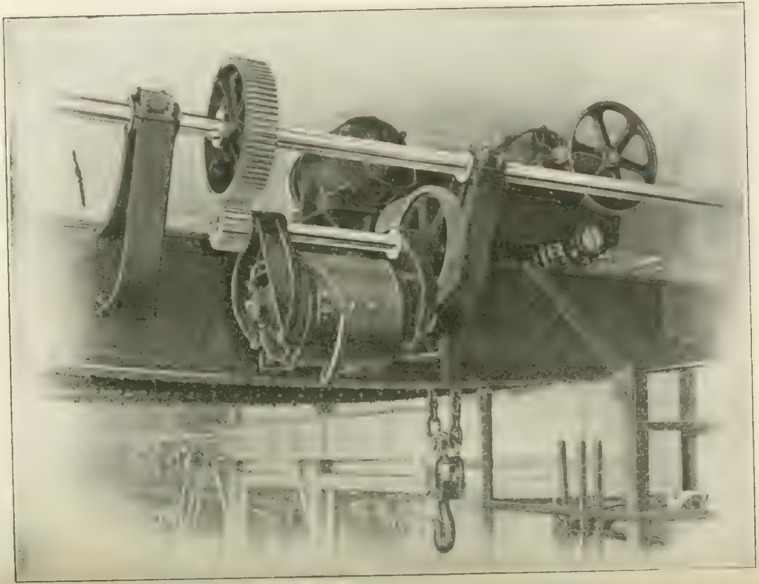


Fig. 62.

The **standard taper** for drill shanks may be considered to be what is known as the Morse. This taper is $\frac{5}{8}$ inch to the foot. There is another known as the Brown & Sharpe or Jarno which has a taper of $\frac{6}{10}$ inch to the foot. No attempt should be made to run the drills of one taper in the sockets of the other.

A flat taper key, introduced into the key way, engages the end of the tongue and serves to remove the drill from the spindle.



ELECTRIC CRANE DRIVEN BY WESTINGHOUSE TYPE L MOTORS

Drills of cylindrical form are also made with straight flutes as shown in Fig. 63. They are used for drilling soft metals, such as brass, especially when the drill passes entirely through the piece. As it breaks through the metal, a drill with spiral flutes tends to draw itself through rapidly, as if it were a screw working in a nut. This may break the drill or move the work from position. Straight flutes give the same cutting action as a flat drill and avoid this tendency to draw.

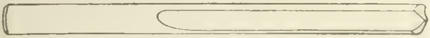


Fig. 63.

Lubrication of Drills. When drilling tough metals such as steel, wrought and malleable iron, heat is generated by the bending or changing of the form of the metal being removed and by friction caused by the chips moving over the lips of the drill. The heating is similar to the heating of a piece of wire bent quickly back and forth. As there is danger of heating the drill to a temperature that will draw the temper and soften the drill, plenty of lard oil, or a mixture of potash and water, should be used. This is not so much for lubrication as to remove the heat.

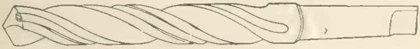


Fig. 64.

Copper is the most difficult to drill of all the common metals on account of its extreme toughness; then, too, copper heats to a higher temperature on account of its low specific heat. Brass does not require the use of oil, and cast iron must always be drilled dry. Particular attention is called to this precaution regarding cast iron.

As the heat is produced at the point of the drill, it is desirable, particularly in the case of deep holes, that the oil be applied directly at the drill point. For this purpose, oil-tube drills, such as is shown in Fig. 64, are used.

The oil is supplied under pressure, and not only removes the heat, but also carries away the chips.

Speed of Drills. The speed at which drills should be rotated depends on the diameter of the drill and the material operated upon. No absolute rule can be given for any one metal or diameter of drill, because of the variation in hardness and tenacity of the material and the condition of the cutting edge of the drill.

The following table of revolutions per minute, given by the Cleveland Twist Drill Co., is based on a peripheral speed of 30 feet a minute for mild steel, 35 feet per minute for iron, and 60 feet per minute for brass.

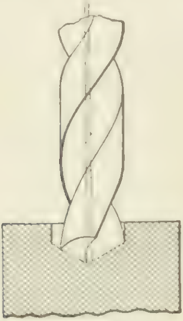


Fig. 65.

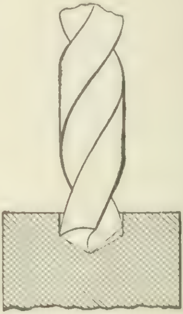


Fig. 66.

The rate of feed also depends on the drill diameter and the material. The above mentioned authority gives, as a maximum, one inch of feed for 95 to 125 revolutions.

Grinding Drills. Great care should be exercised in the grinding of drills. The end of a drill should be symmetrical; that is, the lips should be of the same length, and form the same angle with the axis. If the lips are of unequal length, the hole will be larger than the drill, as is shown in Fig. 65. The point is not in the axis, and the hole will not only be large but also will not be parallel to the drill spindle. If the lips do not form equal angles with the axis, all the cutting will devolve upon the one making the greater angle as shown in Fig. 66. Such a drill will not cut as fast as, and will become dull sooner than, one which is properly ground.

Hand-grinding, especially of twist drills, is neither accurate nor satisfactory; it is much better to do such work on a regular drill grinder built especially for the purpose.

SPEED OF DRILLS.

Diameter of Drill.	Speed for Soft Steel or Wrought Iron.	Speed for Cast Iron.	Speed for Brass.
1/16	1824	2128	3648
1/8	912	1064	1824
3/16	608	710	1216
1/4	456	532	912
5/16	365	425	730
3/8	304	355	608
7/16	260	304	520
1/2	228	266	456
9/16	203	236	405
5/8	182	213	365
11/16	166	194	332
3/4	152	177	304
13/16	140	164	280
7/8	130	152	260
15/16	122	142	243
1	114	133	228
1 1/16	108	125	215
1 1/8	102	118	203
1 3/16	96	112	192
1 1/4	91	106	182
1 5/16	87	101	174
1 3/8	83	97	165
1 7/16	80	93	159
1 1/2	76	89	152
1 9/16	73	85	145
1 5/8	70	82	140
1 11/16	68	79	135
1 3/4	65	76	130
1 13/16	63	73	125
1 7/8	60	71	122
1 15/16	59	69	118
2	57	67	114

While grinding, care must always be exercised that the cutting edge is not overheated on the stone or emery wheel. If it is overheated, the temper will be drawn and the drill become too soft to properly do its work. The angle between the front face of the drill and the bottom of the lip may be from 70 to 80 degrees. This will give ample clearance for the bottom of the drill and leave sufficient metal to support the cutting edge.

REAMERS.

It is difficult, if not quite impossible, to drill a hole to an exact nominal diameter. For most work, a variation of a few hundredths of an inch from the nominal diameter is of no account. Where greater accuracy is required the holes are reamed; that is to say, the hole is first drilled somewhat smaller than it is desired, and is then reamed out to the proper size with a reamer.

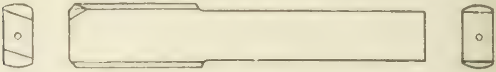


Fig. 67.

Holes drilled with the flat chuck drill mentioned above are usually $\frac{1}{16}$ inch under the finish size. A flat chuck reamer, Fig. 67, is used to enlarge the hole to within about .005 inch of the true size. This reamer is centered on both ends and turned to size.

Fig. 68.

The entering end, which does the cutting, is given a short, sharp taper, while the straight portion serves as a guide to keep the tool in position. By this means the drilled hole is straightened and brought close to size.

To give the hole a smooth surface and correct diameter, a fluted reamer (of which there are various forms) is used. This tool is not intended to remove large amounts of metal, but serves only to increase the size of a hole by a small fraction of an inch up to the diameter required. The hole should not be more than $\frac{1}{64}$ inch smaller than the reamer; this will leave $\frac{1}{128}$ inch on each side for the reamer to cut. If possible, it will be better to drill the hole even nearer than this to the required diameter.

It is evident that if the reamer were to be made of the same diameter throughout its whole length, it would be very difficult to make it enter the hole. In order to facilitate this, it is usually made slightly tapering, for a distance from the entering end, equal to about one diameter.

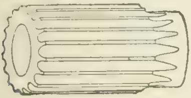


Fig. 69.

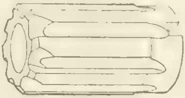


Fig. 70.

One form of reamer has a shallow screw thread cut at the entering end. This thread takes hold of the metal and draws down into the work. When using a reamer, it is always well to pass the entire tool through the hole. The leading end is subjected to the greatest amount of wear because it does the greatest amount of work. If, therefore, only the leading end is put through, the hole will not be of a uniform diameter throughout. Oil should always be used on reamers when they are working in wrought iron or steel.

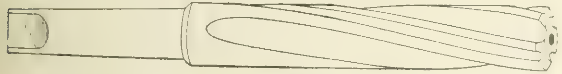


Fig. 71.

The hand reamer, Fig. 68, is the typical form, and one which can be used in many cases in place of special forms. Fig. 69 is better adapted for use in the lathe than the hand reamer. This may follow the flat chuck reamer to finally finish a hole.

In reaming cored holes, the cylindrical chuck reamer, sometimes called the roughing reamer, is often used. It is made either rose, Fig. 70, fluted, or with three spiral flutes, Fig. 71, and generally have solid shanks. The last-named style will finish very smooth and close to size when started true by preliminary boring.

A solid reamer cannot be sharpened without reducing its diameter; therefore, it must be used carefully in order to prolong its life. Reamers with adjustable blades meet this objection, but cost much more than the solid form. An expanding reamer, Fig. 72, can be slightly enlarged to compensate for grinding, and is then used as a solid reamer. Fig. 73 shows an adjustable reamer with inserted teeth.

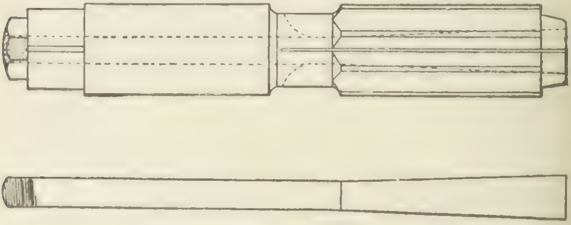


Fig. 72.

Reamers are made for tapered as well as for straight holes. The angle varies with the intended use of the taper; for example, the *locomotive taper* of $\frac{1}{16}$ inch per foot is intended for bolt holes where plates are to be drawn solidly together and the holes completely filled. It is very difficult to remove a bolt from a hole with such a slight taper. When pieces are pinned together, such

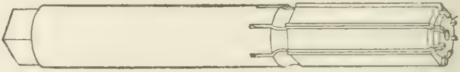


Fig. 73.

as a hub to a shaft, it is intended that they can be separated when desired, so the taper is made steeper, generally ¼ inch per foot. This has come to be known as the *pin taper*. Taper holes for holding lathe centers and taper shank twist drills are generally made ⅝ inch per foot (*the Morse taper*). This angle holds the tool firmly, and still it can be easily removed. The three tapers mentioned are recognized as standard, and reamers for them are carried in stock. Of course many other tapers are used by different manufacturers, but they are regarded as special. Fig. 74 shows taper reamers.

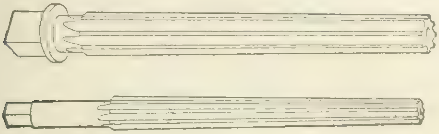


Fig. 74.

Taper reamers differ from hand reamers only in the angle and by not requiring the tapered entering end.

Holes to be reamed by taper reamers must be slightly larger than the small end of the reamer; and, if the hole is deep, it is usual to make a stepped hole, shown exaggerated in Fig. 75, by using drills of different diameters.

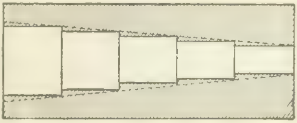


Fig. 75.

When not carefully sharpened, all forms of reamers have a tendency to chatter and produce rough surfaces. To avoid this, the flutes are frequently irregularly spaced; another method is to use spiral flutes, usually left-hand.

TAPS.

When internal thread cutting is done, the tool is called a tap. There are many styles of taps; the names in some cases are suggested from the shape, but more often from the use. In most machine shops are found the following forms: hand, machine screw, pipe, pulley, stay-bolt, boiler, and tapper; of these the hand and machine screw are the most common. The object of all is to make spiral grooves, called threads, in holes, so that they may receive and hold screws, bolts, studs, etc.

As the size of a tap is the diameter outside the threads, it is evident that the hole drilled for tapping must be smaller than the tap by nearly, if not quite, twice the depth of the thread. The shape of the thread partly determines the amount to be subtracted from a tap diameter. There are now recognized as standard, five different threads, viz.: sharp or V, Franklin Institute or United States standard, Whitworth, International or metric, and the 29° or Acme. These shapes will be described and compared under Screw Cutting. The following table shows the diameters of the holes that are to be drilled for cutting the various sizes of the threads according to the United States standard and the ordinary V-thread.

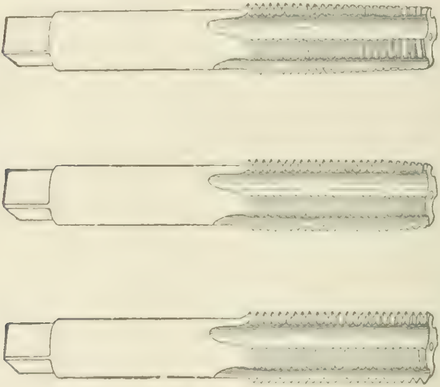


Fig. 76.

Hand taps are most commonly used in shop practice, and a description of the operation will answer for all styles. They are usually sold in sets of three, — taper, plug, and bottoming. See Fig. 76.

The cutting of a thread with a tap is not difficult, but requires care in the manipulation. The tap does not need to be forced into the work, since the thread will draw it forward. The tapering of the tap has a two-fold effect. No one thread must do all of the work in the removal of the metal; each succeeding thread removes a small amount until the full thread has entered the hole. The second effect is that, as in the cases of a reamer, the tap is easily entered and started. Care must always be exercised at this point of the work. The taper of the tap allows it to easily enter the hole, and also makes it possible for it to enter at an angle. If

TABLE OF TAPS AND CORRESPONDING DRILLS.

Tap. Diameter in Inches.	No. Threads per Inch.	U. S. Standard Drill Diameter.	V-Thread Drill Diameter.	Tap. Diameter in Inches.	No. Threads per Inch.	U. S. Standard Drill Diameter.	V-Thread Drill Diameter.
$\frac{1}{4}$	20	$\frac{3}{16}$	$\frac{11}{64}$	$1\frac{7}{8}$	5	$1\frac{5}{8}$	$1\frac{17}{32}$
$\frac{5}{16}$	18	$\frac{1}{4}$	$\frac{15}{64}$	2	$4\frac{1}{2}$	$1\frac{23}{32}$	$1\frac{21}{32}$
$\frac{3}{8}$	16	$\frac{9}{32}$	$\frac{9}{32}$	$2\frac{1}{4}$	$4\frac{1}{2}$	$1\frac{31}{32}$	$1\frac{7}{8}$
$\frac{7}{16}$	14	$\frac{11}{32}$	$\frac{21}{64}$	$2\frac{1}{2}$	4	$2\frac{3}{16}$	$2\frac{3}{32}$
$\frac{1}{2}$	13	$\frac{13}{32}$	$\frac{25}{64}$	$2\frac{3}{4}$	4	$2\frac{7}{16}$	$2\frac{11}{32}$
$\frac{9}{16}$	12	$\frac{7}{16}$	$\frac{7}{16}$	3	$3\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{1}{2}$
$\frac{5}{8}$	11	$\frac{1}{2}$	$\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$2\frac{7}{8}$	$2\frac{3}{4}$
$\frac{11}{16}$	11	$\frac{9}{16}$	$\frac{9}{16}$	$3\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{8}$	$2\frac{15}{16}$
$\frac{3}{4}$	10	$\frac{5}{8}$	$\frac{19}{32}$	$3\frac{3}{4}$	3	$3\frac{5}{16}$	$3\frac{3}{16}$
$\frac{13}{16}$	10	$\frac{21}{32}$	$\frac{21}{32}$	4	3	$3\frac{9}{16}$	$3\frac{7}{16}$
$\frac{7}{8}$	9	$\frac{23}{32}$	$\frac{45}{64}$	$4\frac{1}{4}$	$2\frac{7}{8}$	$3\frac{13}{16}$	$3\frac{11}{16}$
$\frac{15}{16}$	9	$\frac{3}{4}$	$\frac{49}{64}$	$4\frac{1}{2}$	$2\frac{3}{4}$	4	$3\frac{7}{8}$
1	8	$\frac{27}{32}$	$\frac{13}{16}$	$4\frac{3}{4}$	$2\frac{5}{8}$	$4\frac{1}{4}$	$4\frac{1}{16}$
$1\frac{1}{8}$	7	$\frac{15}{16}$	$\frac{29}{32}$	5	$2\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{4}$
$1\frac{1}{4}$	7	$1\frac{1}{16}$	$1\frac{1}{32}$	$5\frac{1}{4}$	$2\frac{1}{2}$	$4\frac{3}{4}$	$4\frac{1}{2}$
$1\frac{3}{8}$	6	$1\frac{5}{32}$	$1\frac{1}{8}$	$5\frac{1}{2}$	$2\frac{3}{8}$	5	$4\frac{3}{4}$
$1\frac{1}{2}$	6	$1\frac{9}{32}$	$1\frac{15}{64}$	$5\frac{3}{4}$	$2\frac{3}{8}$	$5\frac{1}{4}$	5
$1\frac{5}{8}$	$5\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{5}{16}$	6	$2\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{1}{4}$
$1\frac{3}{4}$	5	$1\frac{1}{2}$	$1\frac{13}{32}$				

it is started in the latter condition, the thread will not be at right angles to the surface. The degree of care needed in the starting of the tap depends upon the job that is to be done. In the case of tapping a nut, it will usually be quite sufficient to set the tap by the eye. In finer classes of work, however, the tap should be set with a square. Start the tap into the hole, and place a square on the surface beside it in two positions at right angles to each other, and see that the tap stands parallel to the vertical blade.

When holes have been drilled that are to be tapped, a good way of setting the tap is to put a center in the drill spindle. Put the tap into the hole, and bring this center down into the center hole in the head of the tap; this will steady the latter while it is being started.

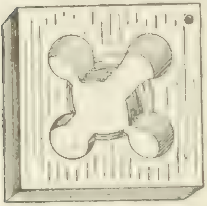


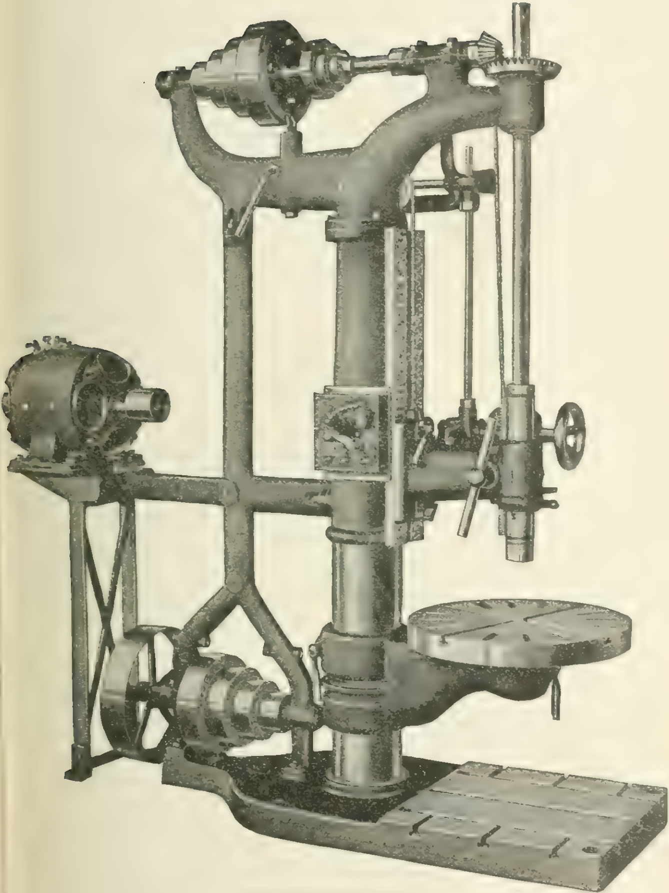
Fig. 77.

In using the tap, it is well to work it back and forth. This allows the chips to work clear of the cutting edges, and the oil to cover them. In case of heavy work, it is possible to drive the tap with the drill spindle, but when thus driving a tap in a machine, the backing up is impossible.

Sometimes a thread is to be cut down to the bottom of a hole that does not pass entirely through the metal. In this case the bottoming tap is used. This is a tap that is not tapered at the entering end. The method of working is to first cut the thread as far as possible with the plug tap, and then use the bottoming tap, which will then enter easily and can be driven to the bottom.

Machine tapping is best done by using a frictional tap-holder; that is, one in which the friction is enough to cut the threads, but which will slip when the tap strikes the bottom of the hole. This will insure the hole being tapped to the bottom, and avoid all danger of breaking the tap. To withdraw the tap, the machine is reversed, usually at a higher speed than used in tapping.

When tapping wrought iron and steel, a plentiful supply of



MOTOR-DRIVEN DRILL.

oil should be used. On brass the use of oil is unnecessary, while cast iron should always be tapped dry.

DIES.

Dies are used for cutting threads on bolts and other similar parts to be placed in holes which have been threaded by taps.

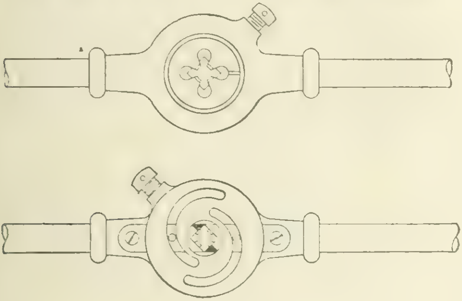


Fig. 78.

The general rules given for the use of taps apply to dies. As the number of threads in a die is much less than on a tap, and because the chips have a much freer exit, it is not as necessary to back up a die as it is a tap.

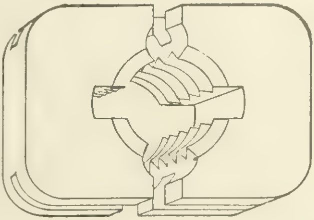


Fig. 79.

Dies for small work are usually made solid, as shown in Fig. 77, and often have a slight adjustment for altering the size. They cannot be sharpened, but have an advantage in readily centering on the work. As the full thread is cut at one passage of the die, it takes considerable power to operate solid dies of large size. For this reason, hand-operated solid dies are seldom used above one-half inch. The holder or die stock shown in Fig. 78 has a guide to hold the work at right angles to the die, but die stocks are often made without this convenience.

The split form of die, generally known as the jamb-die (shown in Fig. 79), can be easily sharpened, has unlimited adjustment for size, and cuts the thread by easy stages, as it were.

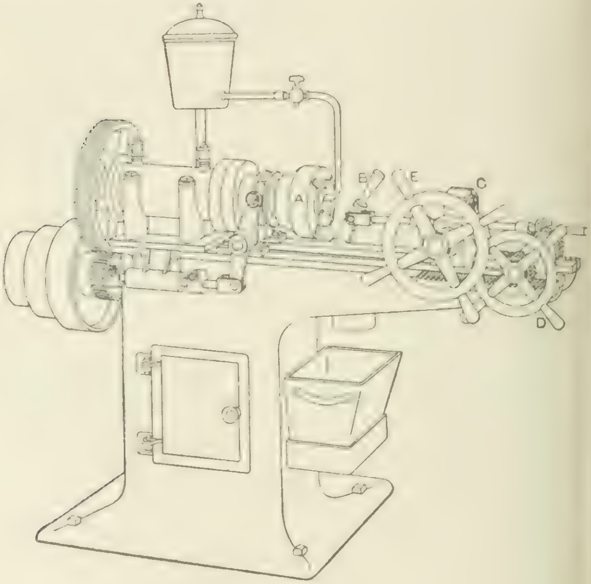


Fig. 81.

It is made in sizes up to two inches, and is for hand operation only. The holder for this form of die is called a screw plate, Fig. 80. These are not furnished with guides for the work.

Cutting Pipe Threads. Another common form of thread cutting is that on wrought-iron pipe. The pipe thread is rounded slightly at top and bottom, and is made tapering at the rate of three-quarters of an inch per foot. The dies are usually solid, square in form, and the die stocks are provided with a ring, which fits over the pipe and serves to hold it square with the die. This avoids the danger of cutting the thread at an angle with the pipe axis.

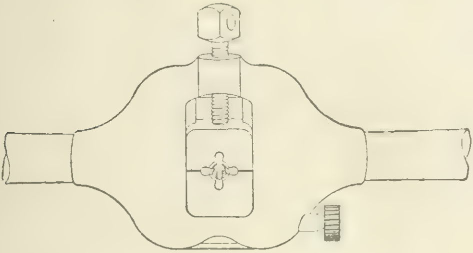


Fig. 80.

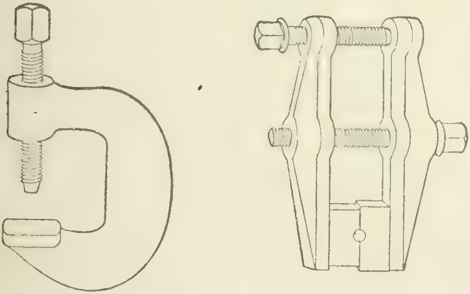


Fig. 82.

Comparatively little thread cutting is done by hand. A large proportion of all such work is performed on bolt-cutters. This is ordinarily the roughest and cheapest class of work, and the running of the bolt cutter is usually the first work to which the apprentice is assigned.

Bolt-Cutter. An ordinary type of bolt-cutter is shown in Fig. 81. The dies are held in the head A. Instead of being solid, as in Fig. 77, they are made in sections, and can be opened or closed by the movement of the lever B. A chuck, C, is placed on a traveling head, and this can be moved back and forth by the hand-wheel D. The method of working is very simple. The dies in the head are closed in order to be in the working position. The bolt to be cut is gripped in the chuck by turning the handle E, and forced against the dies by the handle D. As soon as the dies have taken hold, they draw the bolt ahead. When a sufficient length of thread has been cut, the dies are opened and the bolt withdrawn. This avoids the necessity of backing out, as would be required if the dies were solid. While the thread is being cut, the dies are kept flooded with oil.

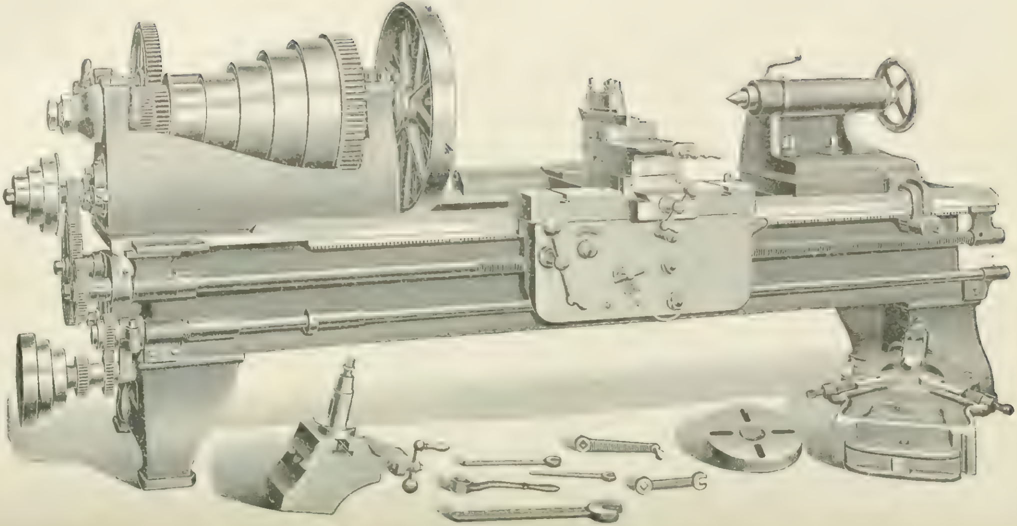
Templets. Where the same piece of work is to be many times repeated, templets are used. This method avoids the necessity of making measurements in the laying out of the work.

The *marking templet* consists of a piece of the same shape as the finished article. It is usually laid on a flat surface, and held fast by iron clamps as shown in Fig. 82. The outline is then marked on the surface with a scriber, and sometimes emphasized by prick punch marks.

The *filing templet* is of the same character as the one just described, but it is hardened. It is clamped in the vise with the piece to be shaped, and the surface filed down to coincide with the form of the templet.

Where holes are to be drilled in duplicate, a templet known as a *jig* is used. These jigs are made so that they fit over the piece to be drilled, and, when clamped in position, indicate the location of the holes by means of hardened steel bushings set in the templet.

The making of templets and jigs is one of the finest branches of the machinist's work, and is generally classed under the head of tool making. The rapid and economical production of machine parts in quantity depends largely on the tool maker, who must, therefore, be considered the highest type of machinist.



24-INCH SWING ENGINE LATHE
F. E. Reed Company

MACHINE SHOP WORK.

PART II.

THE LATHE.

The lathe is one of the most ancient of tools, and is a development of the potter's wheel. The spindle is horizontal and the work is revolved while the cutting tool is stationary. In its

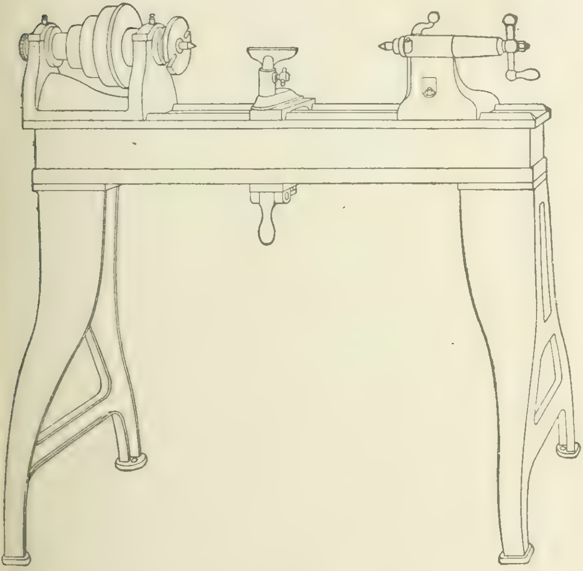
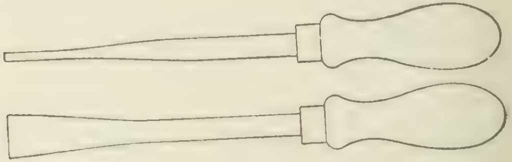


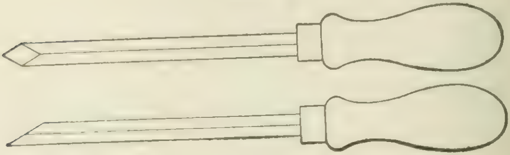
Fig. 83.

various forms and sizes it is by far the most important tool in the machine shop. It is built in a wide range of sizes from the delicate instrument suitable for the work of the jeweler to the great machine capable of turning engine shafts for the largest ocean steamships or the rings for the heavy ordnance of battleships and fortifications.

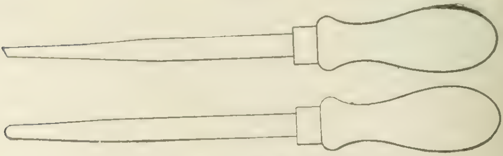
Speed Lathe. The small lathe used in the machine shop for the operations of hand turning, filing, and polishing is called the hand or speed lathe, Fig. 83. This type driven by foot power is in great favor with amateur workmen. While hand turning is avoided as much as possible, it cannot be wholly eliminated, and a brief description of the tools used and the operations performed seems necessary.



Planisher.



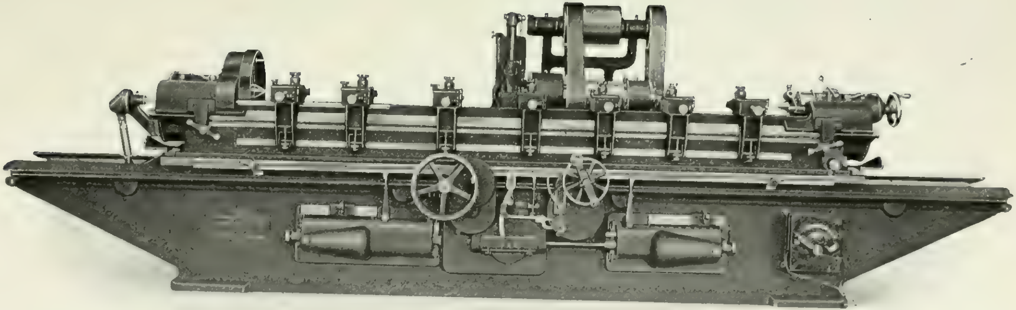
Graver.



Round Nose.

Fig. 84.

The tools used on brass and composition cut by a scraping action, and are almost always held at or below the center. The three tools shown in Fig. 84 called the planisher, graver, and round nose, are typical of all the tools necessary for turning brass.



FRONT VIEW OF GRINDING MACHINE SHOWING ELECTRIC DRIVE.
Norton Grinding Company.

etc. The manner of holding these tools in connection with the T-rest is illustrated by the planisher in Fig. 85. Fig. 86 shows another view of the T-rest. Typical hand tools for cutting iron and steel are the diamond point or graver and the round nose,

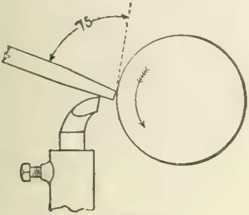


Fig. 85.

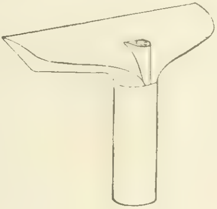


Fig. 86.

shown in Fig. 87. They are used differently from hand tools for brass, in that the cutting edge is carried above the center, and the metal is removed by cutting instead of scraping. The graver frequently takes the place of the planisher, for it can be used as shown in Fig. 88, either on the outside or on the end of a piece of work. The round nose is used solely for concave surfaces being held as high on the work as proper cutting will allow; Fig

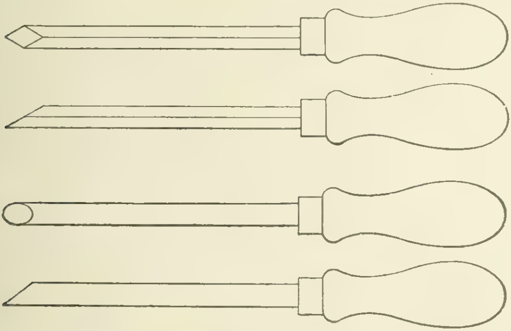


Fig. 87.

89. The graver can be used on brass for a great variety of operations; but its use, except in the hands of an expert workman, is attended with danger of catching in the soft metal and thus breaking the tool or spoiling the work.

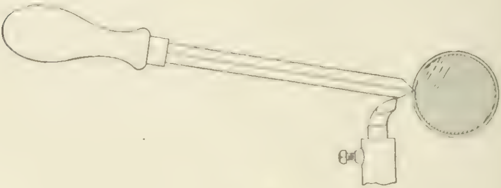


Fig. 88.

To make the hand lathe more rapid and certain in operation, it is frequently provided with a tool holder, called the slide rest, Fig. 90. This holds the tool rigidly and guides it mechanically, so that the work is done more rapidly than with hand tools. Slide rest tools are miniatures of those used on larger lathes, hence a description will not be given at this point.

Engine Lathe. When the slide rest is permanently attached to, and movable along, the bed of the lathe, and motion is automatically imparted to the tool, we have what is termed the engine lathe. This is one of the most common, as well as one of the most important machine tools, and one which can be made to serve for a wide variety of operations. For these reasons, it is entitled to a more extended description than that accorded to less typical forms.

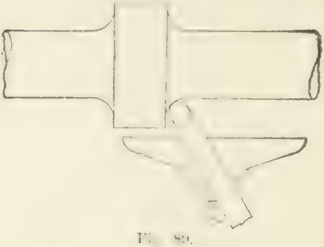


Fig. 89.

An ordinary form of screw cutting engine lathe is shown in Fig. 91, which is a representation of one of usual dimensions. It has a strong cast-iron bed A, carried on four well braced legs, that may be bolted to the floor, though the weight of the machine may be sufficient to hold it in position. On the left-hand end of the bed there is fastened the head stock B, which carries the main running gear of the machine. At each end of the head stock there is a bearing for the spindle. Running loosely on the spindle and between the bearing is the cone pulley C to which the pinion D is attached.

The back gear is designed to reduce the speed of the spindle without changing the belt speed. The mechanism of the back gear is more clearly shown in Fig. 92. The large gear E alone shows in Fig. 91. It is driven by the pinion D which is attached to the cone. The pinion on the same sleeve as the gear E drives the gear at the right of the cone. This gear is keyed to the spindle. When the back gear is not in use it is thrown out of mesh with the gears on the pulley and spindle, by means of the shaft having eccentric bearings upon which it turns; at the same time the cone pulley is fastened to the gear at its right. The spindle then turns with the cone pulley. When the back gear is in use the spindle runs more slowly, with the belt on the same step of the cone, than it does when driven direct.

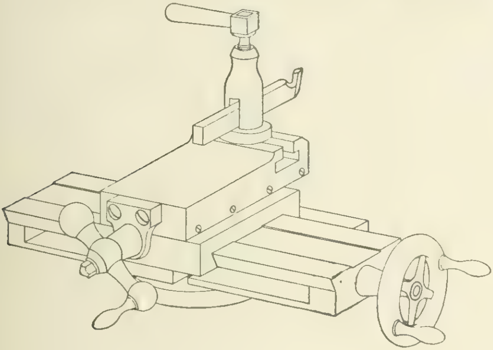


Fig. 90.

The spindle projects through the bearings at each end. At the right it is usually threaded to receive a face plate F. It is

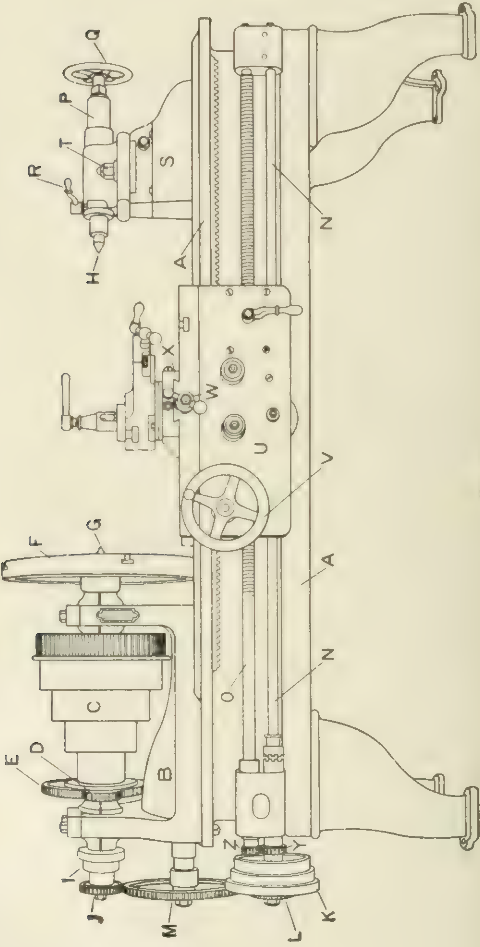


Fig. 91.

also bored out and tapered at the end for a center G. This center is called the *live center* because it turns with the spindle. The *dead center* H is in the tailstock, and hence does not turn. At the left the spindle projects beyond the bearings, and carries a small cone pulley I and a pinion J. The cone pulley serves as the driving pulley for a narrow belt running to the corresponding pulley K on the feed rod N. The pinion serves to drive, through the intermediate gear M, the lead-screw O.

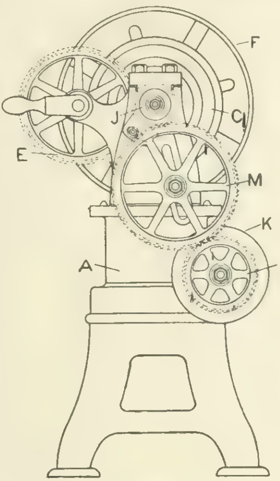


Fig. 92.

The work is held on the centers G and H, the distance between which is adjusted by moving the tailstock S (sometimes called the tailblock). The latter is held to the bed by a clamp and bolts tightened by the nuts T. To move the tailstock, these nuts are slackened and the stock moved to the proper position. The final adjustment is made by turning the hand wheel Q, which rotates a screw in the case P, which works in a nut in the spindle of the dead center H which is thus moved in and out. When the centers have been properly adjusted and the work is in position, the dead center is clamped by the handle R.

When work is to be turned, the tool is properly adjusted, and the carriage U moved along the bed. This movement is accomplished by means of gearing, which is placed behind the apron of the carriage, and driven by the shaft upon which the cone pulley K is keyed. The driving gear meshes with a rack beneath the upper ledge of the bed. Connection between the gearing and the shaft is made by a friction clutch. The carriage may also be moved by hand, by turning the hand wheel V, to which there is keyed a pinion directly meshing in the rack.

The tool is fed to the work and withdrawn from it by turning the cross feed handle W. This drives, by means of the screw and nut, the cross slide X. This arrangement permits any desired transverse or longitudinal position of the tool. The motion of the carriage is usually from right to left when at work. When screws are to be cut, a different feed is used. In ordinary turning there will be a variation in the relations between the rotation of the work and the longitudinal motion of the tool due to the slipping of the belt connecting the cone pulleys I and K, or to the slipping of the friction clutch connecting the shaft K to the driving gear. To cut a screw thread it is necessary that there shall be no relative change in the rotation of the work and the longitudinal motion of the tool. In other words, the tool must travel a given distance for every revolution of the work. To accomplish this, the carriage is driven by the lead-screw O working in a nut set in the carriage. The screw is, in turn, driven by the train of gears J, M, and L. The gear J is keyed to the spindle. The intermediate gear M runs loose on a stud. The gear L is keyed to the feed rod N, which transmits its motion to the lead-screw O by gears Y and Z. By changing the sizes of the gears used on the spindle and the screw, any desired thread may be cut. The size of the intermediate gear M has no effect on the thread being cut. It is used to connect the other two gears, and can be adjusted to any desired position for that purpose.

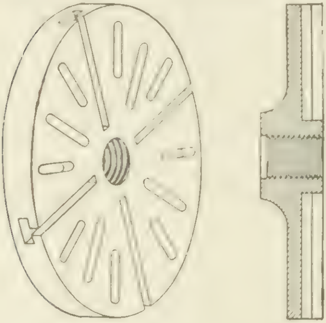


Fig. 93.

In this country the SIZE OF A LATHE is designated by the largest *diameter* it will swing over the guides, and by the length of the bed. The lathe illustrated is known as 24″ × 8′. In England the distance from the guides to the center is the unit of size, and, in a few cases, the greatest distance between centers is considered to be the length of the lathe. Thus a 15-inch lathe in England would be a 30-inch lathe in the United States.

The attachments usually furnished without extra charge are a large face plate of the full swing of the lathe, a steady rest, and a follower rest.

The small face plate is used only for driving the work indirectly through suitable attachments. The large face plate shown in Figs. 91 and 93 is used as a direct support for the work, the T-slots and other openings furnishing opportunities for bolting and clamping the work firmly to the face plate.

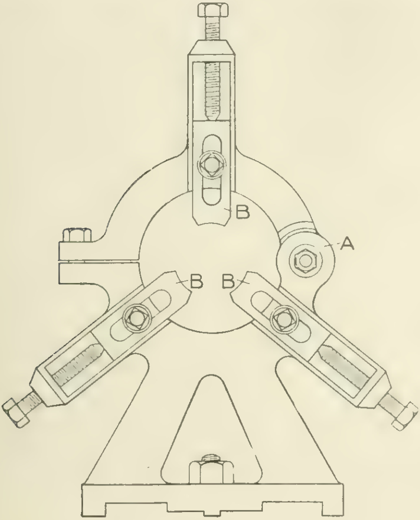


Fig. 94.

The Steady Rest. When work is being done on the end of a shaft so that the tailstock cannot be used, it is necessary to support the shaft in some other way. It is done by means of the steady rest shown in Fig. 94. This rest consists of a frame hinged at A, and fitted with three movable jaws, B B B. The rest is clamped to the lathe bed in the proper place. The jaws B B B are then adjusted to form a bearing for the work, care being taken that the axis of the work is parallel to the ways, or shears. Unless it is parallel, the work will not be turned true; that is, the end will not be square, but will be hollowed or conical, as shown somewhat exaggerated in the accompanying diagram (Fig. 95). The steady rest is also used to support long shafts that are being turned; it prevents such work from sagging at the center and thus being turned out of true.

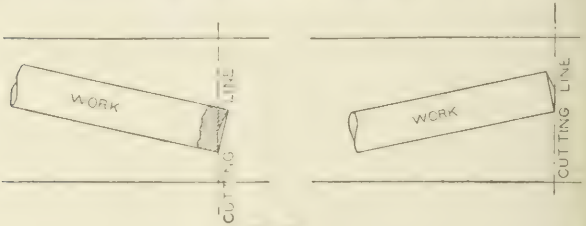


Fig. 95.

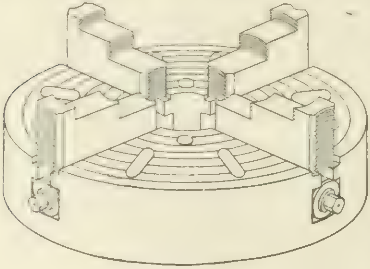


Fig. 97.

After adjusting the steady rest to size, it can be moved along the bed of the lathe without changing the relation to the lathe axis; but care must be taken not to reverse the steady rest in the lathe, as, in most cases, such action would necessitate a readjustment.

The names, back rest and center rest, are synonymous with steady rest, the use of the device often determining the name.

The follower rest serves some of the purposes of the steady rest, but is fastened to the carriage, and moves with it at the point of greatest stress. It may consist of adjustable jaws or a solid ring to slip over the piece being turned. It is especially valuable in turning shafting and other work where the ratio of length to diameter is very great. The follower rest is not very often used in shop practice, except on classes of work just mentioned. The extra attachments desirable for a lathe will now be briefly described.

Chucks. First in importance is the lathe chuck, Fig. 96. It consists of a body which is fastened to a special face plate in such a way that it is concentric with the spindle. The three jaws AAA can be moved in and out toward the center by turning the screwheads BBB. These chucks are universal or independent. In the universal chuck all of the jaws are operated simultaneously. That is, when one of the screw heads B is turned, all of the jaws are moved an equal distance towards or away from the center. This makes it possible to put the work in position quickly if it is approximately round in its unfinished condition. With the in-

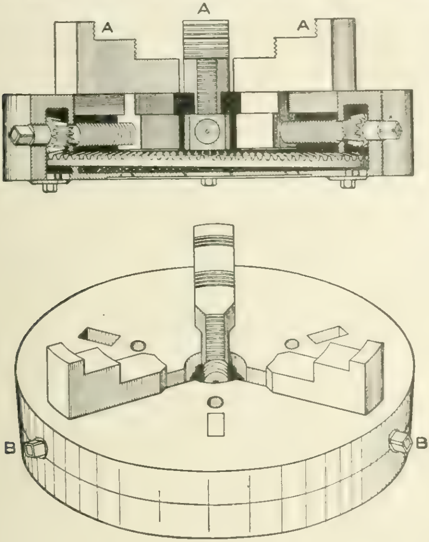


Fig. 96.

dependent chuck, Fig. 97, each jaw is operated separately. Such a chuck is used for holding pieces of irregular shape and those which must be held eccentrically. Frequently the universal and independent chucks are combined in one. Means are then provided for working the jaws separately or together as desired.

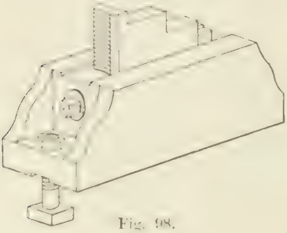


Fig. 98.

In using the universal chuck each screw should be tightened. The method of procedure is to place the work in the chuck, and turn one screw head until all of the jaws are in contact with the piece to be operated upon. Then turn the chuck and tighten each screw head successively until each one is tight enough. Owing to wear and lost motion, it is sometimes necessary to apply the wrench to each one three or four times before the final adjustment is reached.

Lathe chucks are usually made with three or four jaws. Universal chucks generally have three jaws, while independent chucks have four. It follows that a combination chuck is not wholly satisfactory, because with three independent jaws it is very difficult to adjust work accurately, and with four universal jaws it is equally difficult to get every jaw to bear on the work. For certain classes of work, especially valves and pipe fittings, chucks with two jaws are often used.

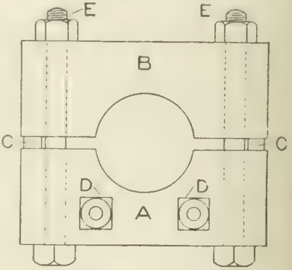


Fig. 99.

The large face plate of a lathe can be made into an independent chuck by attaching what are known as face-plate jaws; Fig. 98. In this case, there may be six, eight, or more jaws.

As these chucks are expensive it sometimes happens that a piece is to be held for which no provision is made. A chuck can then be made of wood. Such a chuck is shown in Fig. 99. Two pieces of wood, A and B, are bolted together by the bolts EE, while separated by the filling pieces CC. The piece is firmly bolted to a face plate by the bolts DD. The lathe is then run at high speed, and the interior bored out exactly the size of the piece that is to be held. The nuts of the bolts EE are slackened and the filling pieces CC removed. The work is then inserted, and by tightening the nuts EE, it is securely clamped between the pieces A and B.

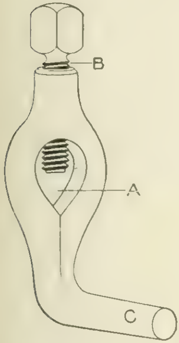


Fig. 100.

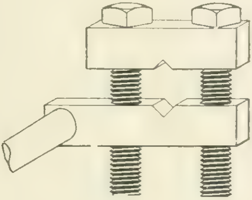


Fig. 101.

Lathe Dogs. As the frictional contact of the work on the live center is not sufficient to turn it, some device must be used to make the work turn with the center. To accomplish this a lathe dog is used. For round work, such as shafting, a dog like that shown in Fig. 100 is often used. The shaft or piece to be turned is placed in the hole A, and held firmly in place by the set screw B. The tail piece C is put through a hole in the face plate and the work rotates with the live center.

While this type of dog is satisfactory in most cases, the fact that the contact between the dog and the face plate is beyond the end of the piece, introduces a bending strain which is appreciable in slender work. To avoid this, dogs are made with a straight tail, and driven by a stud projecting from the face plate.

For work other than round, a dog such as that shown in Fig. 101 may be used. The work is placed between the jaws, and held in position by the bolts. The holes in the upper jaw are made larger than the screws in order that the angle between the jaws may be varied. The connection between the face plate and dog is made as with Fig. 100.

Fig. 102.

Mandrels. Another method of holding work is by the use of a mandrel. This is a piece of steel with a slight taper; the ends are flattened for the lathe dog, as shown in Fig. 102. It frequently happens that a piece with a hole in it is to be turned or finished over its outer surface. In this case a dog cannot be used, and it is troublesome to hold it to a chuck. Such a piece is shown in Fig. 103. This is a stuffing-box gland. If it were to be held by the jaws of a chuck the face A could not be reached at all, and only a portion of the edge B, whereas a dog clamped to it would offer even greater obstruction. The method of using the mandrel is to ream the gland out, so that it can be driven upon

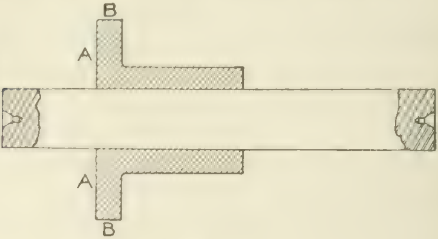
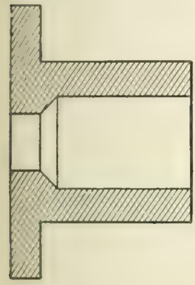


Fig. 103.

the mandrel. When this has been done the frictional resistance between the two will be sufficient to drive the piece. In this manner it can be finished over its whole surface with but one setting in the lathe. All finishing possible may be done while it is in the chuck, leaving, in this case, only the face A and edge B to be finished while on the mandrel.



Should the gland be shaped, as shown in Fig. 104, it would be necessary to make a special mandrel to fit the bore. The cylindrical part of A of the mandrel must be a driving fit, and the part B a loose fit.

Expanding Mandrels. Where a mandrel like that shown in Fig. 102 is frequently used, the constant driving on and off of the work will wear it to a smaller diameter, causing it to become useless. Again, solid mandrels are usually made of standard diameters, varying by sixteenths of an inch. It sometimes happens that a piece to be turned has a hole which will not fit any standard solid mandrel.

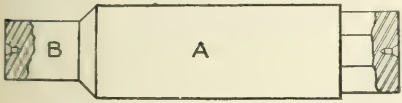


Fig. 104.

To overcome these difficulties an expanding mandrel, shown in Fig. 105, is used. This is really a chuck so arranged that the grips can be forced out against the interior of the hole. When the work has been finished the grips are again drawn in and the piece removed. Another form of expanding mandrel is shown in Fig. 106.

Centering. A piece to be turned is supported on the two centers of the lathe. In order that this may be done, the ends are prepared by drilling a hole in each and countersinking it. This is called centering the work. The countersink should be of exactly the same angle as the lathe center upon which it is to run. The hole should be drilled deep enough so that the point of the lathe center may not strike. The shape of the hole is shown in Fig. 107. The angle of the hole varies from 40° to 90°, but 60° is the generally accepted standard. The effect of using a 60° hole on a 90° center is shown in Fig. 108. The result of such an application is that the bearing will be concentrated on a line AB causing rapid wear of the outer end of the hole, and a cutting of the dead center.

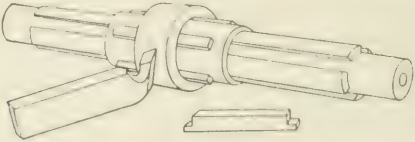


Fig. 105.

The size of center holes varies with the weight of the work and the character of the operation. Heavy work and rough turning require large center holes, while small work and fine turning can be done without countersinking deeply. As bearing surfaces in cast iron must be large to be satisfactory, center holes in cast iron are likely to give trouble by unequal and rapid wear. When turned work in cast iron must be very accurate, it is well to drill a large hole in each end, drive in a plug of wrought iron or mild steel, and form the center holes in the plugs thus driven.

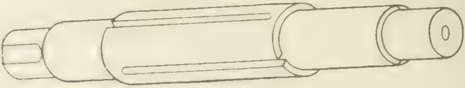


Fig. 106.

When the piece has been put in place, the dead center should be oiled and screwed up into position. It should be tightened so that there is no lost motion and yet allow the work to turn freely.

The turning of shafts and bars is not, however, the only kind of work to be done on a lathe. Pieces are to be turned that are thin, that have holes through the center, and which are so shaped that they cannot be held upon the centers. In such cases it becomes necessary to hold the work firmly without distortion, as may be done by use of the lathe chuck.

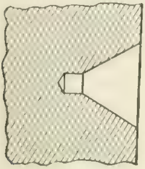


Fig. 107.

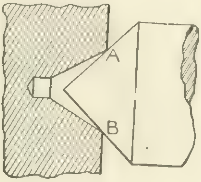


Fig. 108.

Still another method of holding work is that shown in Fig. 109. The piece is clamped to the face plate. When this is done there should be a bearing on the face plate immediately beneath the clamping strap. For example consider Fig. 110. Suppose a disk having four feet on one side is to be faced off on the front.

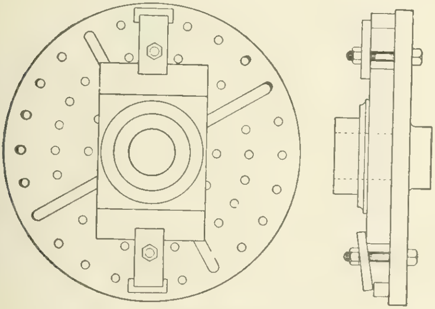


Fig. 109.

The clamps should be placed directly over the feet as in B. If they are placed between the feet at EE the work will be sprung out of shape as shown by the dotted lines in A. Then, when the tool has done its work the shape of the piece, while bolted to the face plate, will be as shown in C. As soon as the pressure of the straps is removed the elasticity of the metal will cause the piece to assume the convex form shown in D, whereas, if the straps had been placed as shown in B, no distortion would have been produced.

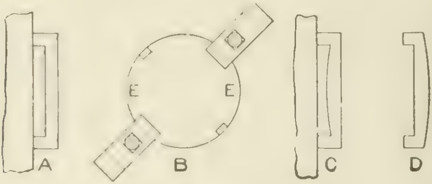


Fig. 110.

An angle iron may be clamped on a face plate, as shown in Fig. 111, presenting a surface parallel to the lathe axis to which work may be attached. The angle irons may of course be at any angle to the face plate, but 90° is the one most commonly used.

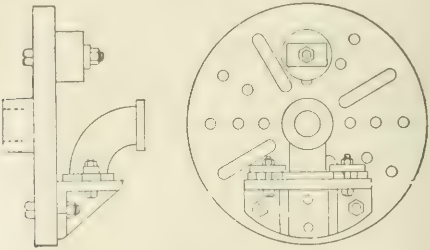
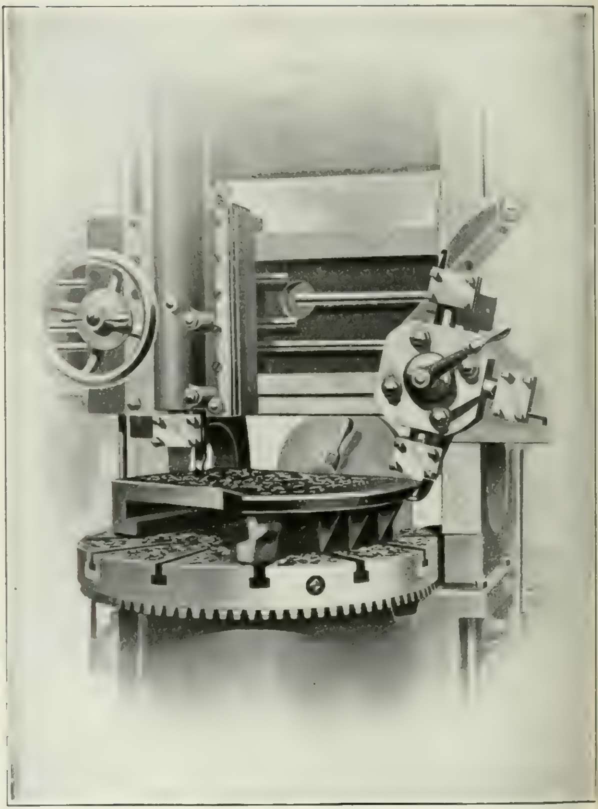


Fig. 111.

When work is held in this manner, it is desirable to counterbalance it, as is also shown in Fig. 111.

Adjusting Pieces to Center. Whenever a piece is to be turned in a lathe it is necessary to adjust it so that its rough outline is approximately concentric with the lathe centers. This is



BORING AND TURNING MILL.

Turning Bevel with Swivel Head.

Bullard Machine Tool Co.

done by bolting it lightly to the face plate and running the lathe. While running, a piece of chalk is held so that the projecting portions will strike it. This marks the piece, and indicates the part that is *farthest* from the center. The lathe is then stopped and the piece shifted, *moving the chalk mark towards the lathe center.* This is repeated until the chalk makes a continuous mark around the whole circumference. The piece may then be considered to be centered.

Suppose it is necessary to center a piece having a hole that must run true. In this case the inside of the hole must be used as a guide. Let Fig. 112 represent the hole with the thin shell, and A a chalk mark made as described for centering by the outside. In this work the *chalk mark must be moved away from the center.* A lathe tool may be used as shown in Fig. 113 to center a piece that is to be bored.

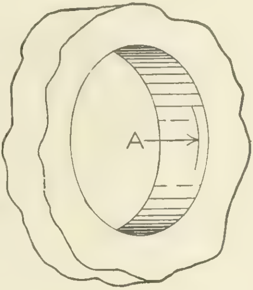


Fig. 112.

Where a piece has already been turned, greater accuracy is demanded, and a surface gage may be used to advantage. Set the gage on the bed or carriage of the lathe, and place one of the points in contact with the work. Rotate the work as before, and note where the point touches the surface. This point is to be treated in the same way as the chalk mark explained in a preceding paragraph.

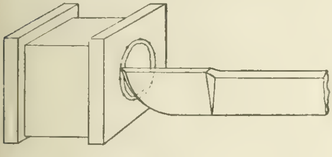


Fig. 113.

A still more accurate method of centering a piece of turned work on a face plate is to use some form of graduated indicator, such as the Starrett indicator, Fig. 114. This is held in the tool post, and the contact point brought against the work until the indicating arm is at zero. If the work is now slowly rotated by hand, the indicator will show just where the work is out of true, and being graduated in thousandths of an inch, will also show how much. By careful adjustment, the piece may be centered to the degree of accuracy required.

Instead of locating a cylindrical surface concentric with the axis of the lathe, it often happens that a point is to be located in the axis. For this purpose, the center indicator, Fig. 115, is used. The free end of the short arm is placed in the point to be centered (usually a prick punch mark), the fulcrum being held in the tool post; when the work is rotated, the free end of the long arm not only shows the error, but magnifies it in proportion of the length of the short arm to the length of the long arm. By using a comparatively long arm, the point can be very closely centered.

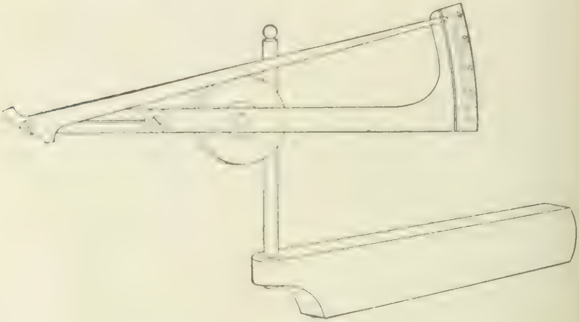
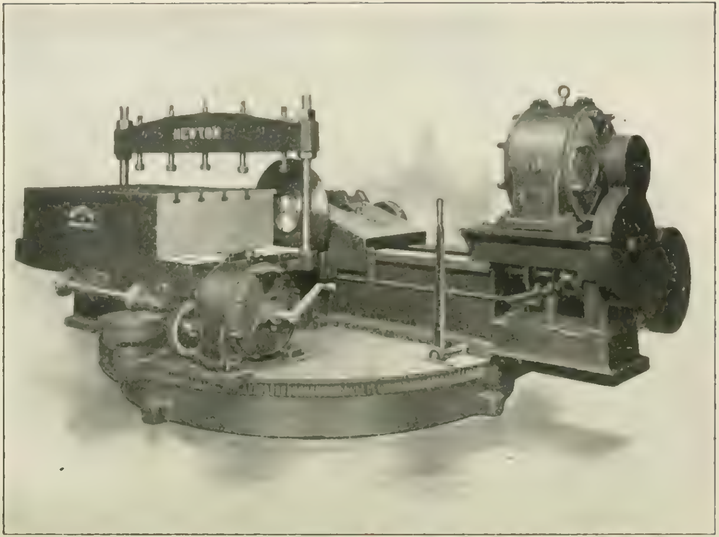


Fig. 114.

Centering Finished Work. After making the center punch mark in the end of the piece, it is drilled and countersunk. This must be done very accurately, but frequently the drilled hole or the countersink will not be in the exact center. See Fig. 116. This may be caused by uneven grinding of the drill, eccentric motion of the drill point (due to the inaccurate running of the spindle), or the distortion of the metal by the center punch. If the countersink is not exactly in the center, it must be drawn back to the center. This is generally done by the small round-



WESTINGHOUSE TYPE C INDUCTION MOTORS DRIVING NEWTON COMBINED COLD SAW CUTTING-OFF MACHINE nosed chisel and a hammer. The method of doing this work is as follows: After making the center punch mark, the hole is drilled and then countersunk slightly. The work should now be stopped; and if the circumference of the conical hole is not concentric with the circumference of the piece a groove should be cut down the side farthest from the outer circumference, as shown in Fig. 117. The depth of the groove, which should be near the center, depends upon the amount of eccentricity. The countersink is again started and the groove drilled out. If the circle is not yet concentric, the process is repeated.

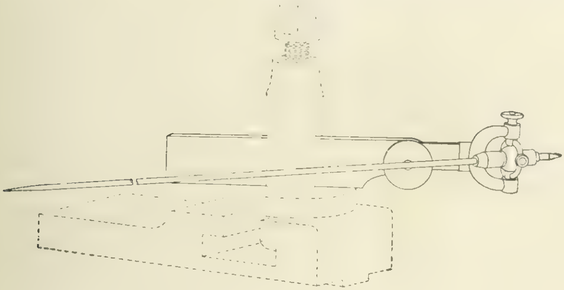


Fig. 115.

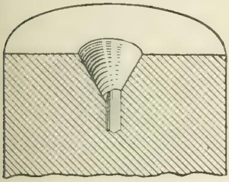


Fig. 116.

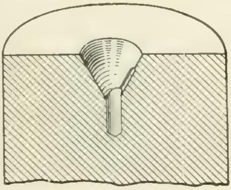


Fig. 117.

Lathe Tools. The cutting tools used in lathes are of a great variety of shapes. These shapes are adapted to the work that is to be done, and to the kind of finish that is to be left upon the metal. There are two fundamental requirements that all tools must fulfill: *The cutting edge alone must touch the metal; the edge must be keen.* A typical form of tool is shown in Fig. 118. The cutting edge of the tool at A is in contact with the work. The bottom line A B runs back from the metal and does not touch it. The top face A C slopes down and back. The line A D is a tangent at the cutting point, and the line A E is radial at the same point. Therefore, the angle D A E is always a right angle or 90°. The angle D A B is called the angle of *clearance*, and should be small; in lathe tools, not over 10°. The angle C A E is called the angle of *rake*, and should be as great as circumstances will permit; about 20° on lathe tools for wrought iron and steel, leaving 60° for the *solid* or *cutting* angle, which is the same angle as is used for a cold chisel.

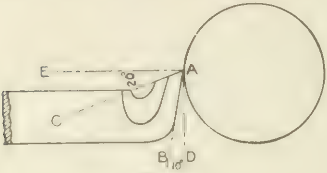


Fig. 118.

Clearance prevents the tool from rubbing on the work, while rake adds to the keenness of the cutting edge, and gives freedom to the removal of the chips. A tool should have sufficient strength at the point to do the work required.

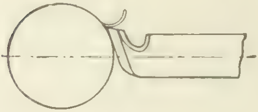


Fig. 119.

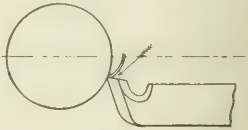


Fig. 120.

The tool should be set so that the cutting edge will be very nearly at a horizontal line, passing through the axis of the work. Many machinists set the cutting edge a little above the horizontal line. When so set the stress tends to force the tool down along the line of its greatest strength. The tool may, however, be set too high. If this is done, as in Fig. 119, the angle of clearance will disappear, and the curve of the work will rub against the bottom of the tool. This will tend to force it out; it will heat the steel and produce a rough surface on the metal being turned. If, on the other hand, the tool is set too low, as in Fig. 120, the cutting edge does not stand in line with the motion of the work at the point of contact. The result will be that the metal will be scraped rather than cut, as there is no rake, and the pressure upon the tool will be in the line of its lowest power of resistance, as indicated by the arrow. Such a position might cause the point of the tool to break off. It will also cause the tool to tremble or chatter as it removes the chips, leaving a rough and wavy surface on the metal.

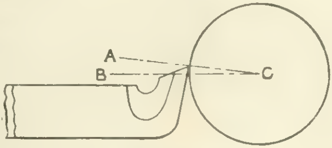


Fig. 121.

As stated above, many machinists prefer to set the cutting edge a little above the center; if this is done, the rotation of the work has a tendency to depress the point of the tool a little, bringing it, while cutting, nearly to the center. The amount the tool is set above the center is slight, and of course depends upon the character of the work. The angle A C B, Fig. 121, should be only about 5 or 6 degrees.

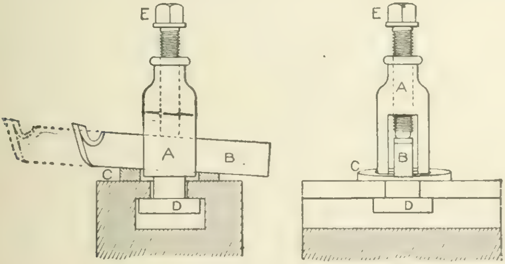


Fig. 122.

The tool is usually held to the carriage by means of a tool post, shown in Fig. 122. The post consists of a piece with a slotted hole through the center for the tool B. A ring C slips over it and rests upon the body of the carriage. This ring may be beveled as shown, to provide vertical adjustment for the point of the tool. The post has a collar D at its lower end that goes loosely into a slot in the carriage. At the top there is a set screw E. When the tool has been properly adjusted by turning the ring C to give it the correct elevation, the set screw is tightened down upon the top of the tool. This raises the tool post to a bearing on the under side of the slot, and clamps the whole carriage firmly in position.

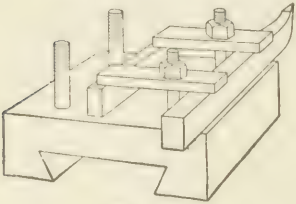


Fig. 123.

In setting the tool, it should be done with the cutting edge as far back towards the supporting ring as possible. If it has too much overhang, as shown by the dotted lines of Fig. 122, it will spring under the pressure of the work and chatter.

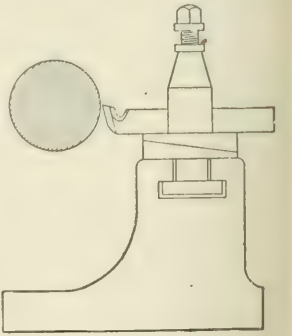


Fig. 124.

While this form of tool post is used more than any other, there are certain objections to it. In the first place, changing the height of the tool point also changes the angles of rake and clearance. These are supposed to be correct when the base of the tool is horizontal. Any change from this position will alter these angles materially. Again, this post is not rigid enough for heavy work. On lathes of over thirty inches swing the style of tool-holder shown in Fig. 123 is often employed.

English manufacturers use it almost exclusively on all sizes. There is no provision for raising and lowering the point of the tool; and while this is not of serious importance on large lathes, 30-inch and over, it becomes a matter of moment when turning such work as is usually handled in lathes of 14-inch and 16-inch swing.

The form shown in Fig. 124 has two beveled rings to adjust the height of the tool.

The Lipe tool post, shown in Fig. 125, combines the good points of all the other forms; the tool can be held by one or two screws as the character of the work may require, and the tool may be adjusted vertically and horizontally after being clamped down. The construction and operation of this tool post are so evident from the illustration, that further description will not be given.

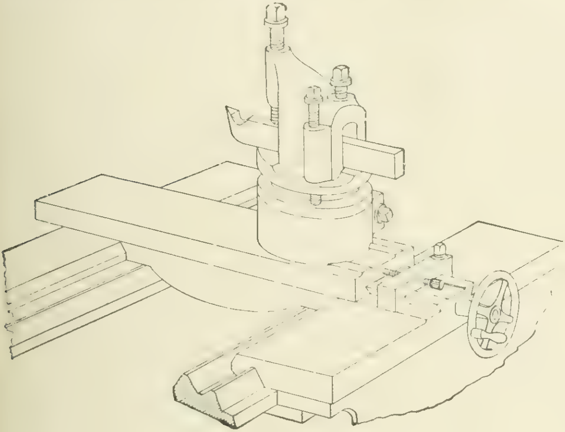


Fig. 125.

An entirely different method of adjusting the tool point is by means of what is called the elevating or rise-and-fall rest shown in Fig. 126. In this type there is a T-shaped casting carried on the upper part of the carriage, supported by trunnion screws at the front, and by an adjusting screw at the rear. With this is used a tool post as shown in Fig. 122 with a plain ring. The elevating rest is used quite extensively on small lathes, but the convenience of adjustment is gained by a loss in rigidity. The cross rail is light, and the elevating portion, being supported at three widely separated points, lacks stiffness. As the effective swing over the carriage is limited by the height of the cross rail and the parts carried above it, they are made light — too light in many cases.

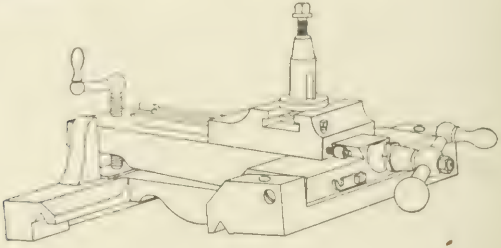


Fig. 126.

Turning Tools. The side or facing tool, Fig. 127, is the most common form of lathe tool. It is used for squaring up the ends of shafts, facing shoulders, and similar work. While the ordinary forms will not remove a large amount of metal, they can, when made thick and heavy, be used for roughing cuts on the surface of cylindrical work. The common form is made slender in order to work between the dead center and the work in squaring up ends.

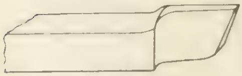


Fig. 127.

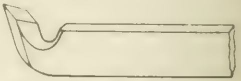


Fig. 128.

A common form of tool for turning wrought iron and steel is the diamond point shown in Fig. 128. The name is derived from the shape of the top face. This tool has both front and side rake which allows a keen edge without reducing the strength. It is used for finishing only when the point is ground slightly rounding and a fine feed is used. In finishing, but little metal should be removed. The *Feed* of a tool is the amount of longitudinal advance at each revolution of the work. For roughing out cast iron, a strong and rapid working tool is a round nose with considerable side rake. For finishing wrought iron and steel, a modification of the diamond point, as shown in Fig. 129, is often used. For cast iron, a square-nosed tool, Fig. 130, should be used. It must be carefully ground and accurately set, otherwise it is very likely to gouge into the softer parts of the metal. When finishing wrought iron and steel, the tool should be liberally supplied with oil or soda water. Cast iron must always be worked dry, both in roughing and finishing.

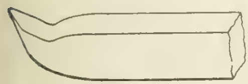


Fig. 129.

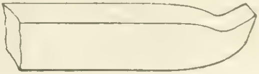


Fig. 130.

The cutting-off or parting tool is illustrated in Fig. 131. The blade is quite narrow; as narrow, in fact, as the character of the work will allow. This is necessary in order that the stock may not be wasted. As the blade must be narrower at the shank and at the bottom than it is at the cutting edge, it follows that the tool is weak. It must be set horizontally so that, as the tool is fed to the work, the cutting edge only will touch the metal. It must also be set so that the cutting edge will pass through the axis of the work as it is fed to the center. If set too high, it will cease to cut before the center of the work is reached, while if too low, the tool has a poor scraping action, and will leave a portion of the work uncut. On work held between centers, one should not

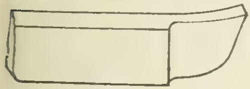


Fig. 131.

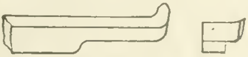


Fig. 132.

attempt to cut to the center of the piece, as the work will surely ride up onto the tool.

Boring Tools. When a hole is to be bored in a lathe, tools of a different shape from those used in turning must be used. The general form of the tool is shown in Fig. 132. The length of the shank at A depends on the depth of the hole to be bored, for it must be long enough to reach from the tool post to the bottom of the hole. This overhang makes the tool more likely to spring, and necessitates a much lighter cut than can be taken when removing the same amount of metal by outside turning tools. The result of this lighter cut is seen in the increase of time required to remove a given amount of stock. The shape of the cutting edge is practically the same as that of the tools for turning, except that the boring tool must have more clearance to avoid striking the work. Therefore, with the same solid angle, the tool will have less rake. The reason for this will be seen by comparing Figs. 118 and 133. In Fig. 118 it will be seen that the surface of the work is outside a tangent at the cutting point, and can never interfere with the bottom of the tool. In Fig. 133 the work surface is inside the tangent; and, unless the tool has a large amount of clearance, it will cause trouble by striking the concave surface.

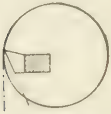


Fig. 133.

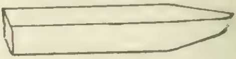
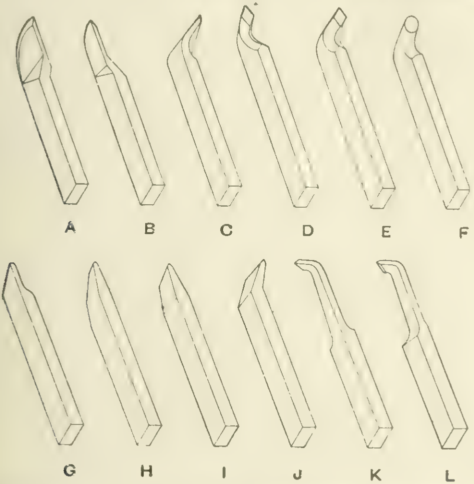


Fig. 134.

Tools for brass differ from those used on steel and iron in that they have no rake. A tool suited for brass is shown in Fig. 134. Brass is a very brittle metal, and the chips break off as soon as started from the main body. When turning wrought iron and steel, on the other hand, the metal does not break, but forms long spiral chips if the tool is in good condition. If a tool with rake is used in turning brass, the work will not only be rough in appearance, but there is great danger of the tool gouging into the stock and spoiling the work or tool, possibly both. The finishing tools for brass may be square or round nosed, without rake; in fact, a small amount of negative rake will produce a much better surface. When the brass contains a large percentage of copper, some rake may be required owing to the ductility and toughness of the metal.

Fig. 135 shows common forms of lathe tools.

The shape of the tool has a very important influence on the amount of work it can be made to do. As has already been explained, these shapes vary with the different metals that are being worked, and also with the class of work performed. It is highly important that the cutting angles be correctly formed. While hand grinding on the emery wheel and grindstone is fairly satisfactory, the best results can only be attained by the use of a regular tool-grinding machine, shown in Fig. 136. In addition,



A Left-hand Side.
B Right-hand Side.
C Right-hand Bent.
D Right-hand Diamond Point.
E Left-hand Diamond Point
F Round Nose.
G Cutting off.
H Roughing.
I Threading.
J Bent Threading.
K Boring.
L Inside Threading.

Fig. 135.

tools for fine finishing should be carefully whetted on a fine oil stone.

The cutting speed is an important matter. This varies with the shape of the tool, the quality of the metal being worked, and the strength of the lathe. The amount of metal removed in a given time is, therefore, equally variable. It is impossible to make a correct estimate of the time that a given piece of work will require unless all of the above elements are known. For approximate estimates, the speeds of cutting tools may be taken to range about as follows:

In cast iron,	from 30 to 40 feet per minute.
In wrought iron,	from 25 to 30 feet per minute.
In steel,	from 15 to 25 feet per minute.
In brass,	from 60 to 100 feet per minute.

Suppose a wrought shaft 6 feet long and 4 inches in diameter is to be turned. Let the lathe be capable of carrying a feed of $\frac{1}{32}$ inch per revolution. The shaft has a circumference of $4 \times 3.1416 = 12.5664$ inches. To give the tool a cutting speed of 25 feet per minute, the shaft must make $\frac{25 \times 12}{12.5664} = 24$ (about) revolutions, giving a feed of $\frac{1}{32} \times 24 = \frac{3}{4}$ inch in that interval of time. At $\frac{3}{4}$ inch per minute, it will take $(6 \times 12) \div \frac{3}{4} = 96$ minutes to take a cut the whole length of the shaft. The amount of feed is really the governing element. This may be as much as $\frac{1}{16}$ inch per revolution, and, for finishing cuts, may not be more than $\frac{1}{100}$ inch. The depth of the cut also influences the time required to finish a given piece. This may vary from $\frac{1}{100}$ to $\frac{1}{2}$ inch. All depends on the shape of the tool and the strength of the lathe.

The cutting speeds given above are what may be used with the best grades of tool steel, such as Jessop's, but by using air-hardening or tungsten steels, the speed of cutting may be very much increased over the values given above. These high-speed steels are rapidly coming into favor, more especially for heavy roughing cuts. Not only are the cutting speeds increased, but the chip is made heavier both in depth and feed up to the point where the lathe refuses to carry the load. The ability of this quality of steel to stand high temperatures without injury is the feature which enables it to do work at this rate.

For cooling the tool while performing heavy duty, a solution of sal soda is preferable to water, as it prevents rusting of the work and machinery. The lubricant does not assist in the severing of the metal; even with a most liberal supply, it is doubtful if any ever reaches the point of the tool. Its office is simply to keep the tool cool. If a tool becomes overheated, the edge begins to turn over and it becomes dull.

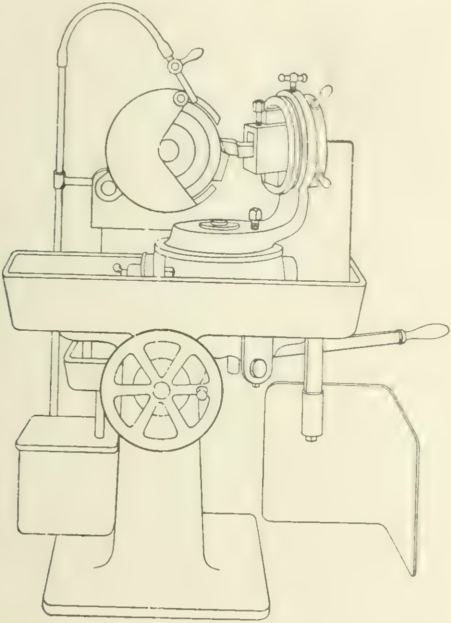


Fig. 136.

Referring to Fig. 120, it will be seen that the chip, as it is being removed, presses down on the top face of the tool. This pressure increases with the depth of cut and the feed. The friction would soon cause a high temperature in the tool if it were not relieved by the lubricant. The lubricant cools the tool by absorbing a portion of the heat, and lessens the amount of heat developed by reducing the friction between the tool and the chip. Clean, pure water is the only lubricant which can be used on cast iron, but the rapid rusting which follows its use makes it undesirable. Brass is also usually turned dry. Prime quality lard oil is sometimes used for cooling the tool; but the greater cost prevents its extended use, unless some means are provided to collect, separate, and filter it.

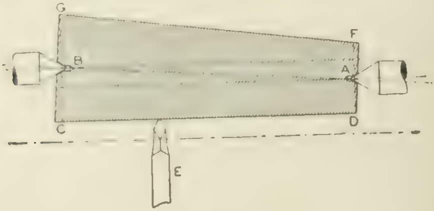
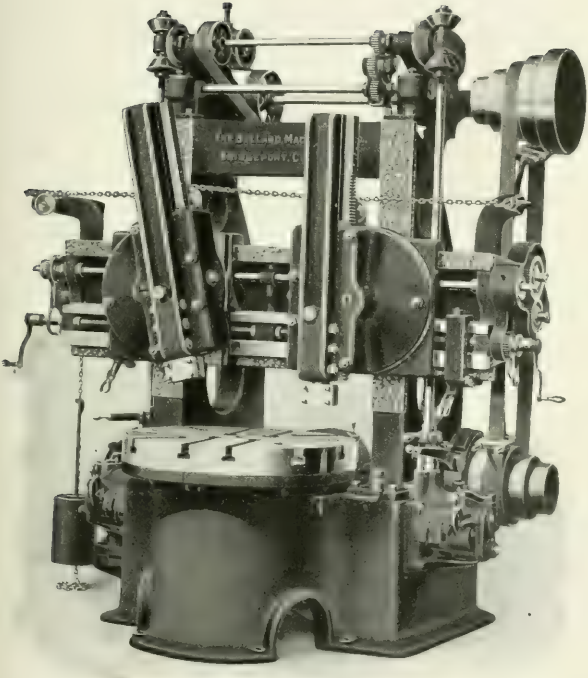


Fig. 137.

Turning. The first operation usually performed on a piece of work when placed in the lathe is facing or squaring up the ends. This must be done to get a uniform bearing for the centers. The finishing of all surfaces at or nearly at right angles to the axis of the work is classed as facing, and the side tool (Fig. 127) is usually employed. For roughing cuts the cutting face of the tool is placed at a slight angle to the work surface in order to remove the metal quickly; but for finishing cuts it is placed nearly flat against the work, so that a light thin chip may be taken.

Turning the cylindrical portions ot the work is next done by the use of the diamond point or similar tool. Roughing cuts are taken to within about $\frac{1}{64}$ inch of the finished size, and a fine finishing cut reduces the work to the exact diameter. For roughing cuts, common calipers should be employed, while for finishing cuts, the micrometer caliper is most suitable. All measurements must be taken with the lathe at rest, as motion of the work renders close calipering impossible.



42-INCH RAPID PRODUCTION MILL.
The Bullard Machine Tool Co.

Turning a Taper. It frequently happens that a piece must be turned tapering; that is, one end is to have a greater diameter than the other. There are three ways of accomplishing this result: setting the dead center over, the use of the compound rest, and the use of the taper attachment. Setting the dead center over is the most common method. Provision is generally made for moving the dead center laterally towards the front or rear of the bed according to the taper required. With the dead center set over, the tool will be at unequal distances from the live and dead centers, because its movement is parallel to the axis of the lathe. This is shown in Fig. 137. The piece to be turned is placed upon the centers A and B, and the dead center is moved from the axis a distance equal to the difference between the radii A D and B C. This leaves the side D C parallel to the center line of the lathe; hence the tool will be fed along this line. The objection to doing work by this method is that the lathe centers do not have full bearings at the ends of the work, and the center holes are likely to wear out of their true positions.

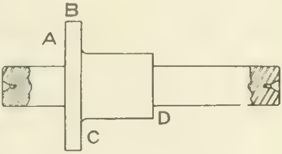


Fig. 138.

If the taper is to be turned on a piece held by a mandrel, or if the taper is to extend but a part of the total length of the work, the amount of set-over for the dead center must be calculated in the same manner as though the taper were to extend the whole length of the mandrel or work. In other words, the amount of set-over for the dead center is determined by the distance between the centers and the rate of taper.

For example: Suppose the mandrel in Fig. 138 to be 16 inches long, and the piece of work C D which is to be turned tapering, is 4 inches long; suppose also, that the diameter at D is to be $\frac{1}{4}$ inch smaller than at C. Then for one inch of length, the difference in diameters would be one-fourth of $\frac{1}{4}$ inch, or $\frac{1}{16}$ inch, and for a length of 16 inches it would be sixteen times $\frac{1}{16}$ inch, or 1 inch. Since the set-over is equal to the difference of the radii, the set-over for the 16 inches would be one-half of 1 inch, or $\frac{1}{2}$ inch.

This, then, would be the set-over for the work under consideration, and for any piece to be tapered at the rate of $\frac{1}{4}$ inch in 4 inches when held on a 16-inch mandrel.

EXAMPLES FOR PRACTICE.

1. A tapered bushing 3 inches long and of 4 and $4\frac{1}{2}$ inches outside diameters is driven on a 12-inch mandrel for turning. How much must the dead center be set out of line in order to do the work? Ans. 1 inch.

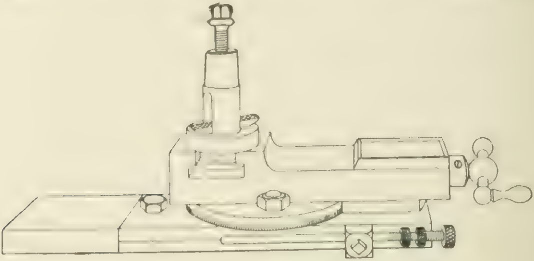


Fig. 139.

2. A connecting rod 6 feet long is to be turned tapering from the center to the neck back of the stub-ends. This distance is 26 inches. The diameter at the center is to be 3 inches, and at the neck $2\frac{1}{2}$ inches. How much offset must be given to the dead center? Ans. .692+ inches.

3. A shaft had a taper 2 feet long turned on one end. The large end of the taper was 4 inches in diameter, and the small end was 3 inches in diameter. The dead center was set over 1 inch. How long was the shaft? Ans. 4 feet.

The machinist generally sets over the dead center as accurately as possible and takes a roughing cut. The taper is then tested by a careful comparison of the diameters or by trying it in a tapered hole of the proper angle, and the center set more accurately. Setting over the dead center does not give accurate results, on account of the fact that the centers do not have a true bearing at the ends of the work. The shorter the work, compared with the amount of set-over, the greater the inaccuracy.

In turning a taper with the compound rest, the work may be held in a chuck, on the faceplate, or between the centers. The compound rest, Fig. 139, is then set at such an angle that the direction of the motion of the tool will coincide with the required taper. Several methods are employed for this adjustment of the rest. The tool is then fed to the work by means of the feed handle attached to the compound rest.

The taper attachment, Fig. 140, is in the form of a guide which is bolted to the back of the lathe. It can be set at any desired angle with the axis of the lathe, the limit usually being a taper of about three inches per foot. The guide is graduated so that calculations based on the length of the work are unnecessary. A slide moving with the guide is attached to the cross-feed of the carriage. The cross-feed is loosened, and, while the carriage is moved by the feeding mechanism, the tool is moved in or out according to the direction of the taper.

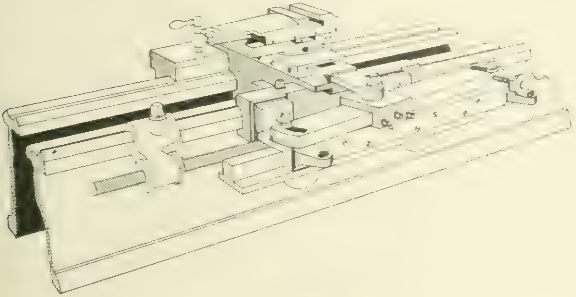


Fig. 140.

One of the most important points to be observed in turning tapers is to have the cutting point of the tool exactly level with the centers. If this is not done, the work will not be truly conical, and, furthermore, the rate of taper will vary with each succeeding cut.

In case an internal and an external taper are to be turned so as to form a fit, the internal taper should, if the character of the work will permit, be made first. After this has been done, the external taper should be turned and tested several times during the process. The external taper is first turned as accurately as possible, taking care that the piece be made a trifle too large. Draw a chalk line on the external taper, from one end to the other, press the tapers together, and give one of them a slight twist. On separating the tapers, the rubbing of the chalk will show where the work was in contact, and, by resetting the lathe and repeating the process, a very accurate fit can be obtained.

Shafting is usually turned $\frac{1}{16}$ inch less than the nominal diameter. For instance, instead of a shaft 2 inches in diameter, one of $1\frac{15}{16}$ inches in diameter is used. The reason is that iron of a nominal diameter of 2 inches, usually $\frac{1}{32}$ inch over size, can be used. Before turning a length of shafting, the rough bar should be carefully straightened. After the center holes have been drilled and the piece placed in the lathe, the work can be turned and the eccentric portions marked with chalk. When this has been done, the bar should be removed from the lathe and sprung back into true alignment. It is well to take two cuts for finishing shafting, one for the roughing cut and one very fine finishing cut. The tool for the latter part of the work should be kept flooded in oil, or a solution of sal soda. If the work is light, a tool-holder, carrying both the roughing and the finishing tools, should be used. This makes it possible to do the work in what practically amounts to the time of one cut.

As a length of shafting is likely to spring under the pressure of the tool, some method of preventing such action must be employed. A steady rest can be used. It is, however, inconvenient and must be frequently moved or it will stand too far, at times, from the tools. Furthermore, as the rough bar will neither be truly round nor concentric with the centers, it is necessary to turn "spots" for the center rest. This operation takes considerable time, owing to the fact that very light cuts must be taken in order to avoid springing the bar. The best method is to have a ring attached to the tool-holder; the internal diameter of this ring is that of the finished shaft. It is slipped over the tail-stock center and follows the finishing tool. It must, of course, be rigidly fastened to the tool-holder. In this way the shaft is supported close to the tools; the ring also serves as a guage to measure the diameter of the shaft. If, for any reason, the tools turn to a larger diameter than the inside of the ring, notice is immediately served upon the workmen to that effect by the binding in the ring.

Eccentric Turning. Up to this point, the work described for the lathe has been of the kind in which the turning is done on work concentric with the lathe centers. There are other classes of work that are offset and for which special provisions must be made. Of course the surface being turned must always be concentric with the spindle.

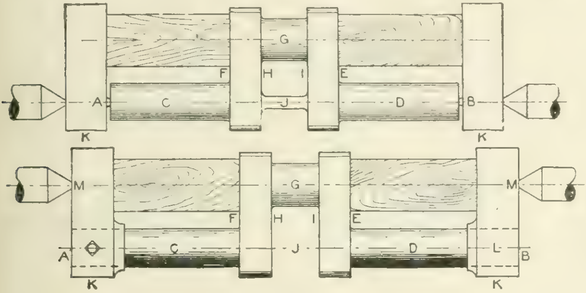


Fig. 141.

The turning of crank shafts presents conditions where there are two cylindrical portions, each parallel to and concentric with the lathe axis while being turned, but eccentric with regard to each other. In Fig. 141 such a shaft is shown. This may be either a casting or a forging. If cast, it is common to have a small web, shown at J, in the original casting to take the thrust of the centers while turning the shaft portions C and D. After centering the work at A and B, the shaft is placed in the lathe, and the ends A and B squared up, and surfaces C and D roughed out. If a forging is being worked, it will be neccessary to insert a wooden block at the point J. Two lugs or ears K are provided to fit tightly on the rough turned shaft, the distance from the center of L to the center M being equal to one half the throw of the crank. These lugs are attached to the ends of the shaft, so that a line joining the centers M will pass through the axis of the crank pin G. Blocks are now placed between the lugs and the crank pin, the web or block at J removed, and the pin turned on the new centers MM. The crank pin G is roughed and finished, and the shoulders H and I faced, at this time. Removing the lugs and blocks, the surfaces C and D are finished and the shoulders E and F faced on the centers A and B. If the shaft is of any considerable weight, it should be counter-balanced by attaching weights to the faceplate. The reason for not finishing the shaft at the first operation, is that removing the scale from a casting or the outer skin from a forging releases internal stresses which are likely to change the shape of the piece. As a general rule, a piece of work should be completely roughed out, if possible, before any finishing cuts are taken. The change in shape, due to the removal of the outer portion of the stock, does not all take place immediately; and, if very accurate results are desired, it is good practice to allow the roughed work to stand some time before finishing.

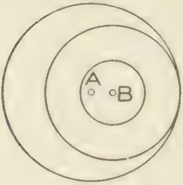


Fig. 142.

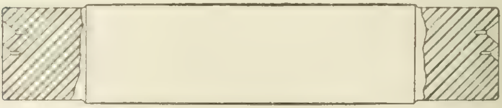


Fig. 143.

Turning an Eccentric. As far as its use in mechanism is concerned, an eccentric is the equivalent of a small crank, but it requires very different treatment in the lathe. In the first place, it is not usually made solid with the shaft, but is a comparatively thin casting or forging which is fastened to the shaft by set screws or keys. The general shape is shown in Fig. 142, and consists of the eccentric proper and a boss to reinforce the shaft hole; this boss usually being on but one side of the casting. In Fig. 142, A is the center of the eccentric and B the center of the shaft.

Small eccentrics, especially those having a throw less than the diameter of the shaft, may be finished in the following manner: The casting is grasped in an independent chuck, one having four jaws being preferred, with the boss or hub running as nearly true as possible. The projecting face of the eccentric, together with the outside and face of the hub, may be machined, and the hole can be trued up with a boring tool or by the use of the chuck drill and reamer. In either case, it is advisable to obtain the exact diameter by using a finishing reamer. The eccentric may now be placed on a special mandrel, shown in Fig. 143, which has an extra set of center holes. A line connecting these holes is parallel to the axis of the mandrel, and at a distance from it equal to one-half the throw of the eccentric. It is obvious that this mandrel is the equivalent of the shaft and lugs used in turning solid crank

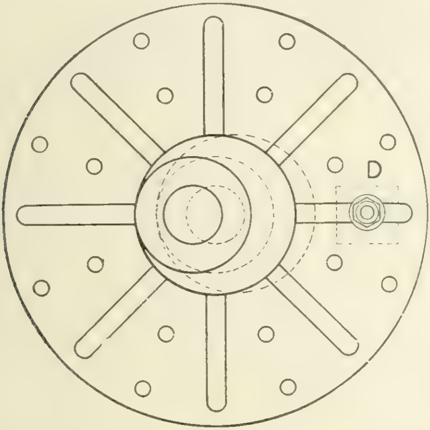


Fig. 144.

pins. On these extra centers the outside of the eccentric may be turned, and, on the regular centers, the back or plain face can also be finished. This completes the eccentric as far as the lathe is concerned.

Large and heavy eccentrics are preferably finished on a faceplate. The plain side or back having been previously machined. the eccentric is clamped to the faceplate with the hub running true, shown dotted in Fig. 144, and the face of the hub and the hole are finished as in the case of the small eccentric held in the chuck. The diameter of the hole being comparatively large, a reamer is not generally used. The eccentric is now moved on the faceplate a distance equal to one-half the throw of the eccentric, bringing the outer surface concentric with the lathe axis, as shown by the full lines, and the clamps placed so as to allow the outside to be turned. It is often necessary to balance the work by counterweights in order to have the lathe run steadily. This is shown at D in Fig. 144.

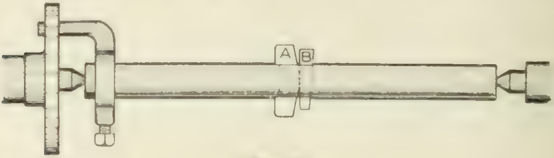


Fig. 145.

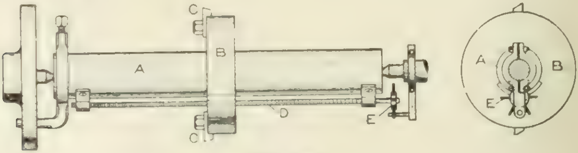


Fig. 146.

Boring. The boring of holes sometimes calls for a length and strength of tool that cannot be readily attained with the ordinary boring tool. A great deal of such boring is done with double-headed tools. These tools are held in bars and cut at each end. An ordinary form of such a tool is shown in Fig. 145.

The tool A is turned and fitted so that when placed in the bar it is central with the centers of the latter. It is held in position by the key B. It cuts at each end. Such a tool may be made to do very rapid work. It is extensively used for boring in places where a piece of work must be duplicated a great number of times.

Tools of this character are used for finishing. After the cut has been started the tool should not be stopped until the cut has been completed. If it is stopped there will be a ledge in the bore at that point. The reason for this is due to the springing of the metal and the contraction due to cooling while at rest. The tools used for finishing usually have a broad surface. Those used for the roughing-cut are narrower; they wear more rapidly than the finishing tools and are usually adjustable. A roughing tool may be held by a wedge as shown at B. Such a tool is placed in position and the wedge tightened just enough to hold it. The adjustment of the tool is then obtained by tapping it with the hammer. It is then held firmly by driving the wedge. An excellent example of this style of work is found in the boring of engine cylinders. Special machines are used for such work. The greater portion of it, however, is done in an ordinary lathe with a boring bar, as shown in Fig. 146. It consists of a heavy bar A, upon which there is a stiff traveling head B. The latter carries the tool C, which may or may not be capable of a transverse adjustment. The head moves longitudinally over the bar and is held,

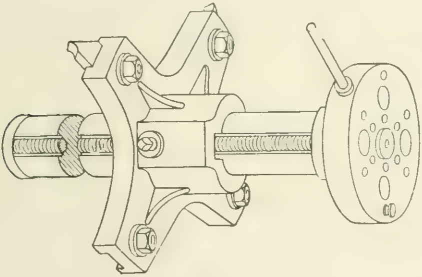


Fig. 147.

adjusted and fed by the screw D. At one end of the screw there is a star wheel, E, by which it is turned. As the bar revolves, one arm strikes against a stop at each revolution. This turns the screw by an amount proportional to the number of arms in the star. For example, if there are six arms in the star, the latter will be turned one-sixth of a revolution for each revolution of the boring bar. As the screw turns, it moves the head along the bar by an amount proportional to the pitch of its thread and the rays or arms in the star. This forms the feed of the tool. For example, if a star has four arms, and is keyed to a screw of eight threads to the inch, then for each revolution of the bar the head will be advanced $\frac{1}{32}$ of an inch. Another form of boring bar is shown in Fig. 147.

Boring bars with fixed tools are also used. In such cases the work is caused to travel beneath the bar as it is turned. A case of this kind occurs in the boring out of brasses for railroad cars.

It may be stated that, in general, all metal work should be finished in the position which it is eventually to occupy. This is due to its tendency to spring out of shape under the influence of its own weight. For small articles this influence is inappreciable. For large pieces it is sometimes quite apparent.

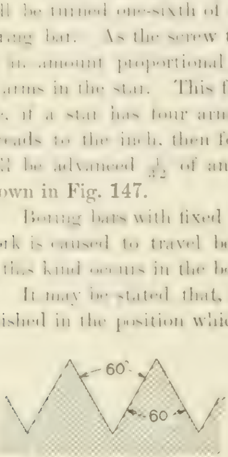


Fig. 148.

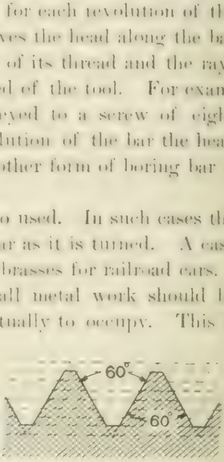


Fig. 149.

SCREW CUTTING.

The tools used for cutting threads are called *screw-cutting tools.* These tools are used in the lathe in the same manner as the diamond point and round-nosed tools. The cutting edge of the tool must be of the same shape as the space between the finished threads.

There are five types of screw threads commonly used in this country: the V thread, shown in Fig. 148, has the form of an equilateral triangle with an angle of 60°. It is sharp at the top and bottom. This thread is difficult to cut because of the trouble experienced in keeping the point of the tool sharp.

A modified form of V thread, known as the Sellers, the Franklin Institute, or the United States Standard, is shown in Fig. 149. This thread has an angle of 60°, with the top and bottom flattened for one-eighth of its depth. It is stronger than the V-shaped thread, and permits greater accuracy in cutting.

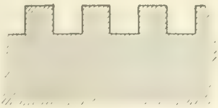


Fig. 150.

Another form in common use is the square thread. This is shown in Fig. 150. The thread and space are of the same width. These screws are used when heavy work is done, such as in jack-screws and presses.

The Whitworth thread is similar to the United States Standard; the slight differences are as follows: the sides form an angle of 55° instead of 60°, and the top and bottom are rounded instead of flat.

The fifth type, the Acme thread, is similar to the square form. The difference is that the sides incline 14½° from those of the square thread. This form of thread is much used for lathe lead screws and for giving motion to sliding parts of fine instruments, because the thread is much stronger than the square form, and the lost motion can be taken up by simply closing the nut halves nearer together.

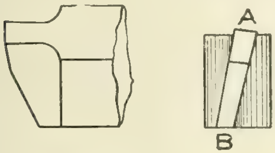


Fig. 151.

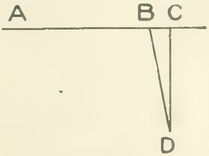


Fig. 152.

The tool used for cutting square threads is shown in Fig. 151. It is of the proper thickness at the cutting edge, but is somewhat narrower back of this point. The sides of the tool are inclined to the body, as shown at A B, Fig. 151; the amount of this inclination varies with the pitch of the thread and the diameter of the piece on which the thread is to be cut. To find the inclination, draw an indefinite straight line A C and at right angles to it draw C D. Make the length of C D equal to the circumference of the thread to be cut, measured at the root of the thread. On A C lay off from C a distance (B C) equal to the pitch; then draw B D. This line will represent the angle of the side of the thread. The angle of the side of the cutting tool must be a little greater for clearance.

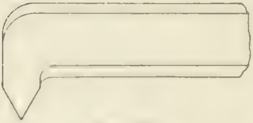


Fig. 153.

For cutting *inside* threads, the shape of the cutting edge of the tool should be the same as for cutting an outside thread, but the tool must be made so that the cutting edge alone touches the work. This is accomplished by bending the tool as shown in Fig. 153 and giving it considerable clearance.

Standard Screw Threads. When screw threads are to be cut, the pitch used depends upon the outside diameter of the bar. A standard has been adopted by all of the leading technical societies of the United States, and is known as the United States Standard. The table (see opposite page) gives the outside diameter of the screw from ¼ inch to 6 inches in diameter, with the number of threads per inch to be cut.

In placing the tool for any form of thread, the point of the tool must be exactly level with the center, and a line at right angles to the axis of the lathe must bisect the angle of the tool point. In order that these conditions may be fulfilled, a thread or center gauge, Fig. 154, is used. In this tool, the angles, A, B, and C are made exactly 60°. The two opposite sides are parallel. The angle A at the end is used for grinding the tool. The sides of the latter are made to touch all along the edge. For setting the tool, the upper parallel side is held against the face of the work in a

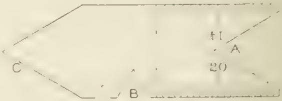


Fig. 154.

horizontal position. The tool is then set so that its sides touch along the edges of the notch B. The angle C is used to gauge the thread after it is cut.

UNITED STATES STANDARD SCREW THREADS.

Diameter of Screw in Inches.	Number of Threads per Inch.	Diameter of Screw.	Number of Threads per Inch.
1/4	20	2	4 1/2
5/16	18	2 1/4	4 1/2
3/8	16	2 1/2	4
7/16	14	2 3/4	4
1/2	13	3	3 1/2
9/16	12	3 1/4	3 1/2
5/8	11	3 1/2	3 1/4
3/4	10	3 3/4	3
7/8	9	4	3
1	8	4 1/4	2 7/8
1 1/8	7	4 1/2	2 3/4
1 1/4	7	4 3/4	2 5/8
1 3/8	6	5	2 1/2
1 1/2	6	5 1/4	2 1/2
1 5/8	5 1/2	5 1/2	2 3/8
1 3/4	5	5 3/4	2 3/8
1 7/8	5	6	2 1/4

The measurement of fine threads is a difficult matter where an ordinary rule is used and the threads between the inch marks are counted. For this purpose a pitch gauge, Fig. 155, is used. The gauges are short screw sections on thin sheets of metal. To ascertain the pitch of any thread, set the gauges over it successively until one is found that exactly fits. The figures stamped thereon will give the number of threads per inch.

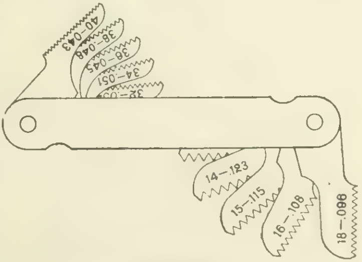


Fig. 155.

The cutting of a thread demands that there shall be a certain definite ratio of motion between the rotation of the work and the travel of the carriage. When a right-handed screw is to be cut, the carriage travels from right to left. For example, if a screw having a pitch of $\frac{1}{4}$ inch, or with four threads to the inch, as it is usually expressed, is to be cut, the spindle must make four revolutions while the carriage is moving one inch along the bed. If the screw is to have eight threads to the inch, the spindle must make eight revolutions to each inch of motion of the carriage or tool; if six threads, then six revolutions to the inch of motion, etc.

If, then, the lead screw is cut with four threads to the inch, it is evident that the speed of rotation of the spindle and of the screw must be the same, in order to cut a screw of four threads to the inch. For each revolution of the lead screw, the carriage moves the distance of the pitch of the same or $\frac{1}{4}$ inch. Hence, the gears, J and L, Fig. 91, must have the same number of teeth. When a screw of eight threads per inch is to be cut, the spindle must make twice as many revolutions as the lead screw. Then, for each revolution of the spindle, the lead screw makes half a revolution and thus moves the carriage $\frac{1}{8}$ inch. In this case, the screw gear L must have twice as many teeth as the spindle gear J. For six threads, the ratio of revolutions between spindle and screw is $1\frac{1}{2}$ to 1. This requires $1\frac{1}{2}$ times as many teeth in the screw gear L as in the spindle gear J.

The rule for finding the gears to be used on the spindle and lead screw is: Multiply the number of threads on the lead screw and the number of threads to be cut by the *same* number; the products will equal the numbers of teeth on the gears to be used.

Suppose the lead screw has four threads per inch and ten threads per inch are to be cut. Multiply both numbers by any convenient number, such as 3. Then the gears should have 12 teeth and 30 teeth.

Let a = the number of threads per inch on the lead screw,
b = the number of threads per inch to be cut,
c = a convenient number,
$a\,c$ = the number of teeth of gear on spindle,
$b\,c$ = the number of teeth of gear on lead screw.

If the gears thus found are not at hand, multiply by some other number. Thus, suppose gears of 30 and 12 teeth were not available, multiply 4 and 10 by 4 or by 5 or any other number that would give the number of teeth on the gears at hand.

Another way to find the gears is to remember that the number of threads to be cut is to the number on the lead screw as the number of teeth on the screw gear is to the number of teeth on the spindle gear.

EXAMPLES FOR PRACTICE.

(1) The lead screw has a pitch of ¼ inch. What is the ratio of gears to be used to cut a screw with 9 threads to the inch? If one gear has 24 teeth, how many should the other have?

Ans. $\begin{cases} 1 : 2\frac{1}{4} \\ 54 \text{ teeth.} \end{cases}$

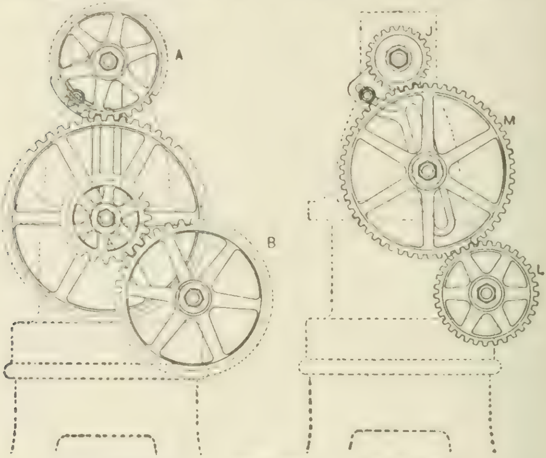
(2) The lead screw has a pitch of ¼ inch. What is the ratio of gears to be used to cut a screw with 16 threads to the inch? Ans. 1 : 4.

(3) The lead screw has a pitch of ⅓ inch. What is the ratio of gears to be used to cut a screw with 12 threads to the inch? Ans. 1 : 4.

In these cases the actual number of teeth on the gears to be used is obtained by multiplying the ratio by some common multiple. Thus in example 1, multiplying by 10 gives 40 teeth for the spindle gear and 90 for the screw gear. In example 2, multiplying by 20 gives 20 teeth for the spindle and 80 for the screw gear; and the same result is obtained by using the same multiple for example 3.

Every screw-cutting lathe is provided with a set of gears from which selections can be made. In order to facilitate the choice of the gears to be used, a *gear table* is usually cast in raised letters and screwed to the front piece of the headstock. This table shows the gears to be used for cutting such threads as may be enumerated on the table.

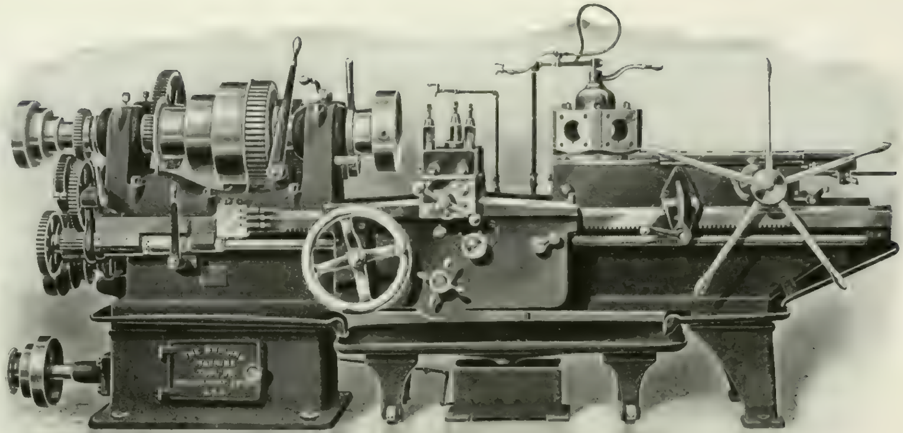
It is sometimes necessary to cut a screw for which there are no gears to make a direct connection. This necessitates the compounding of the gears on the intermediate spindle to replace the single gear. This is done as shown in Fig 156, in which A represents the spindle and B the screw. Suppose, with a lead screw having three threads to the inch, it is desired to cut a screw having thirteen. This makes the ratio of teeth on the spindle gear to those on the screw as 3 to 13. The work can be done with spindle gears having 15, 30, or 45 teeth with screw gears having 65, 130, and 195 teeth respectively. If it is found that there are no gears having 15, 45, 130, or 195 teeth on hand, compounding must be resorted to. To determine the gears to be used it must be remembered that *the product of the numbers of teeth in the driving gears must be to the product of the numbers of teeth of the driven gears, as the number of threads per inch on the lead screw is to the number to be cut.* In this case it is as 3 to 13. Multiply each of these figures by any convenient multiple. In the example in hand, let the multiple be 200. Then



Compound Gear. Fig. 156. Simple Gear.

$$\frac{3\times 200}{13\times 200}=\frac{3\times 2\times 2\times 2\times 5\times 5}{13\times 2\times 2\times 2\times 5\times 5}.$$

Select from the factors thus obtained two sets, each of which, when multiplied together, will give products equal to the number of teeth that are on hand.



TURRET MACHINE.

Swing 26 inches. Bed 10 Feet.

The Bullard Machine Tool Co

Thus in the numerator we may take 3 × 2 × 5 and 2 × 2 × 5, giving 30 and 20 as gears that are to be used as the spindle and intermediate drivers respectively.

For the denominator take 13 × 5 and 2 × 2 × 5 × 2 or 65 and 40, for the driven gears of the intermediate stud and the screw respectively. Placing these in position as in Fig. 157, we have,

Gear A with 30 teeth.
Gear C with 65 teeth.
Gear D with 20 teeth.
Gear B with 40 teeth.

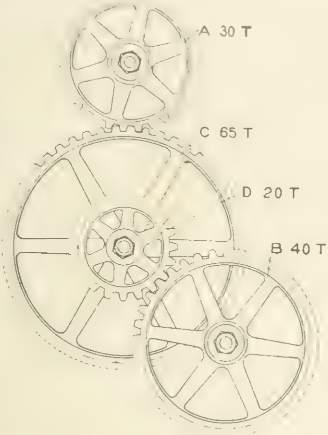


Fig. 157.

It is desired to cut a screw with 11 threads to the inch on a lathe having a lead screw with a pitch of ¼ inch. The gears available have 30, 40, 45, 50, 55, 60, 65, 70, 80, 90, and 100 teeth respectively. What ones are to be used and where?

Ans.	Spindle	40 teeth
	Intermediate driven	55 teeth
	Intermediate driver	50 teeth
	Screw	100 teeth.

Many screw-cutting lathes are not made with an extension of the spindle to receive the first gear, but a short shaft or stud projects from the headstock for this purpose. This stud is geared to the spindle, and the ratio of this gearing must be considered when calculating the gears for screw-cutting. For example, suppose we wish to cut twelve threads per inch in a lathe having a lead screw with eight threads per inch and a ratio of two to one between the spindle and the stud. In other words, the stud runs half as fast as the spindle. As we have seen in the previous examples, the ratio between the spindle and the lead screw must be 12 to 8

The first gear is not attached to the spindle, but to the stud, which makes six revolutions to twelve of the spindle. Therefore, the ratio between the stud and the lead screw, where the gears are actually applied, must be 6 to 8. Multiplying by 6 will give 36 and 48 as the number of teeth in two gears which may be used.

In general, the data that must be given to calculate the change gears for screw-cutting are the number of threads per inch to be cut on the work, the number of threads per inch on the lead screw, and the speed ratio between the spindle and the stud, if a stud is used.

The following examples may be taken as applying to either right- or left-hand threads. The change of direction in the travel of the carriage is obtained by introducing an extra gear into the train, thus reversing the rotation of the lead screw.

The following description of the method of cutting a "V" thread will suffice to illustrate the cutting of any form, with the slight changes which are necessary in the other forms due to the shape of the tool employed.

To cut an ordinary V thread, a V-pointed tool having an angle of 60°, and set so that a line at right angles to the lathe axis bisects the tool angle, and also set exactly at the height of the center, is caused to move at a constant rate parallel to the work surface, while the work is being uniformly rotated.

The relation between the rotary motion of the work and the lateral movement of the tool, determines the pitch of the thread being cut, and the mechanism connecting the work and the tool must be of a positive character; thus eliminating transmission by belts and other frictional devices.

Owing to the lost motion or "back lash" in the mechanism connecting the tool and the work, the tool cannot be returned to the starting point for a new and deeper cut by simply reversing the lathe. The tool must be withdrawn, the lathe reversed, the tool returned to the starting point, and then advanced for the new cut. To place the tool for the new cut with accuracy, a stop or graduated device is provided.

If removed from the lathe for testing, care should be taken in replacing the work to get the tail of the dog in the same slot in the face plate that was used to cut the original thread; this can be done by marking or otherwise indicating it.

Chasing. The ordinary methods of cutting screws have already been described. Where great accuracy is not necessary, the threads may be chased by hand. A chaser, or chasing tool, differs from the ordinary thread-cutting tool, in that it has a number of cutting points instead of but one. When a chaser is operated by a power feed, it is customary to have a shaft revolving at the same rate or at an even multiple of the rate of the lathe spindle. This shaft carries a master thread into which a section of a nut drops. The handle connected with the nut carries the chasing tool. When the nut is in contact, the tool is cutting. At the end of the cut, the tool is lifted out, and with it the nut disengages with the thread.

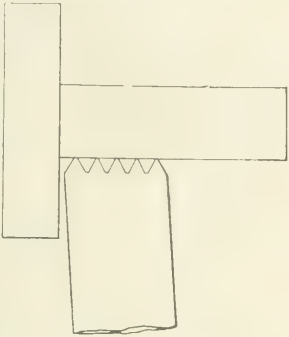


Fig. 158

Hand-chasing requires a great deal of skill in order that a good piece of work may be done. The chasing tool has a number of points as shown in Fig. 158. The work must be run rapidly in the lathe. The tool is held in both hands, and is supported on a rest similar to that shown for the hand-turning tools in Fig. 86. The first left-hand tooth of the chaser is brought lightly against the right-hand edge of the work. The handle is given a quick twist from left to right throwing the teeth in the opposite direction. It is well after the first twist, to stop the lathe and examine the

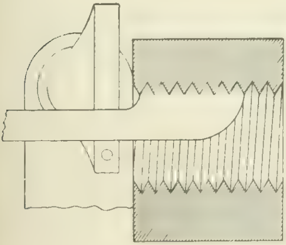


Fig. 159.

work. If the operation has been properly performed, the second tooth will be found to have entered the groove made by the first. A short length of thread will have been cut, the pitch being the same as that of the chaser. If this is correct, the lathe may again be started and the chaser applied as before. On the second trial the thread may be run to its full length. The finishing of the thread is done by merely repeating the operation. A fine cut is taken with each application of the chaser for the whole length of the thread until the full depth has been cut. In doing this work, the rear or right-hand side of the chaser should be pressed more firmly against the piece being cut than the front, because the threads with which that portion of the tool is engaged are more deeply cut than at the front. In addition to cutting, these teeth also guide the front. The reason for running the lathe at a high rate of speed, is that the movement of the chaser is less likely to be checked or thrown aside by seams or inequalities in the density of the metal than it would be if the lathe were to run slowly. Inside threading may be done by means of the inside chaser shown in Fig. 159.

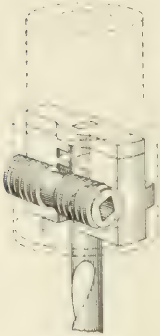
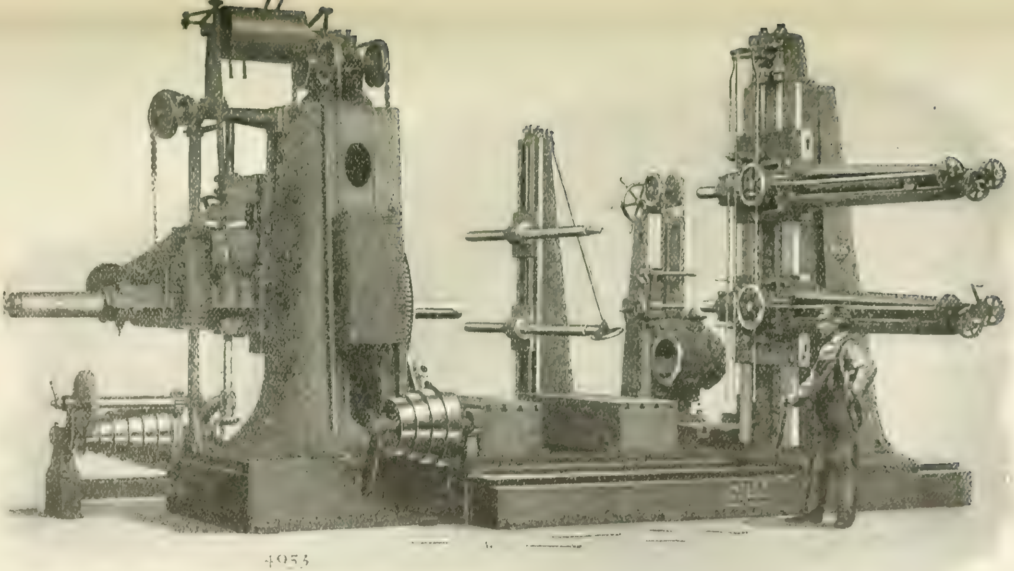


Fig. 160

Drilling in the Lathe. The lathe can also be used for drilling. When such work is to be done, the drill may be held in the spindle and the work forced up against it by the screw of the tail stock: or the work may be revolved and the drill forced in by the tail-stock screw. When the first method is followed the drill may be put into a socket prepared for it in the spindle of the lathe, or the drill may be held by a drill chuck as shown in Fig. 160. This chuck may be used in the tail-stock to hold twist drills, or to hold flat drills which are forged from round stock. Flat drills made from flat stock are centered at the rear end and held against, and fed forward by, the dead center. In this case, a slotted rest held in the tool post prevents the drill from turning (see Fig. 60) and aids in starting the drill true.

When the drill is held in the head stock, the work may be



CYLINDER BORING MACHINE WITH PORT BORING ATTACHMENT.

Niles-Bement-Pond Co.

fastened to the carriage and fed against the drill, or it may be held by means of a suitable device held in the tail stock. For this purpose the drill pad, shown in Fig. 161, may be used, and especially if the work be flat. The V center, shown in Fig. 162, is used when it is desired to drill through the axis of a piece of round stock. The shape of the groove prevents the work from turning and the angle being always in the axis of the lathe determines accurately the location of the hole.

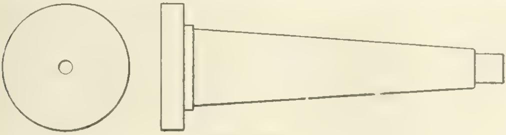


Fig. 161

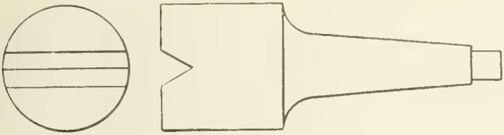


Fig. 162.

THE DRILL PRESS.

This tool is made in a great variety of forms, according to the class of work it is intended to perform. The form illustrated in Fig. 163 is one of the standard makes. The mechanism is very simple and will be briefly explained.

The frame consists of a strong column A, securely bolted to a heavy base-plate B. Power is delivered to the machine by means of a belt running over the cone pulley C. The shaft upon which this cone pulley turns, runs through the casing D, where, by means of miter gearing, it drives the vertical drill spindle E. It will be seen that there are four steps on the cone pulley C, thus affording a means for securing as many rates of revolution of the drill spindle. This, however, is not sufficient to meet all the

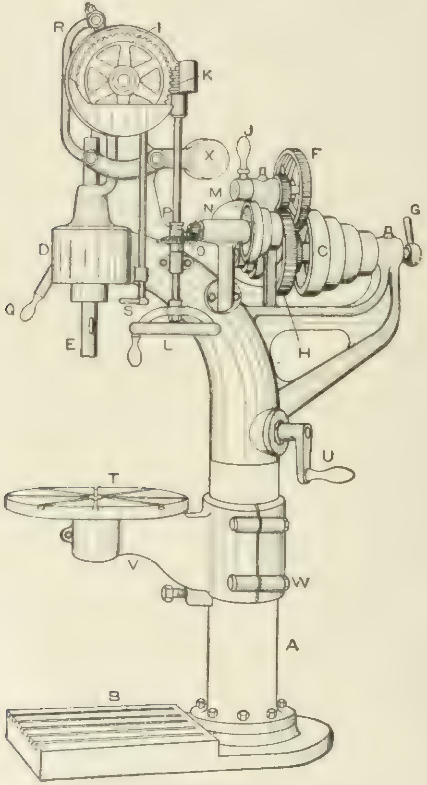


Fig. 163.

requirements of the work that can be done with the tool. In order to increase the range of available speeds, a *back gear* is used. This is shown at F. It consists of a gear and pinion keyed to the same shaft. The cone pulley C is loose on the horizontal shaft, but may be fastened to it by a clutch operated by the lever G. The inner end of the cone pulley carries a pinion that meshes with the gear F, while the pinion attached to F meshes with the gear H that is keyed to the horizontal shaft. The gear F and its pinion run loosely on a journal that is, in turn, attached to an eccentric bearing. By turning the handle J, which is attached to the eccentric bearing, the gears may be thrown in or out of mesh. While the gears are in mesh, the power passes from the cone pulley to the pinion attached to it, to the gear F, to its pinion, and thence to the gear H, and thus turns the shaft. Under these circumstances the shaft is turning much slower than the cone pulley.

The feed, or downward motion of the drill spindle may be accomplished by hand or by power. At the upper end of the drill spindle a rack is cut, into which a pinion on the same shaft as the worm wheel I meshes. It is evident that, as this wheel revolves, the spindle will be raised or lowered.

The weight of the spindle is counterbalanced by the weight X. The worm wheel I is turned by the worm K, which is rotated by the hand wheel L. This serves for a hand feed. For a power feed, a belt is made to drive the cone wheel M. This turns the bevel pinion N, meshing with the bevel gear O, that is loose on the feed shaft. It is fastened to the latter by means of a small clutch P. A quick return of the spindle is accomplished by means of the handle Q. This is attached to the spindle by means of a yoke R. When the quick return is to be used, the worm K is thrown out of mesh with its wheel by turning the handle S.

The table T may be raised or lowered by means of the handle U; this drives a screw in the standard running in a nut fastened to the bracket V. When the table has been adjusted, it may be fastened by the nuts and bolts W clamping it to the standard A. When large work is to be drilled, the table may be swung out of the way and the work bolted to the base plate B.

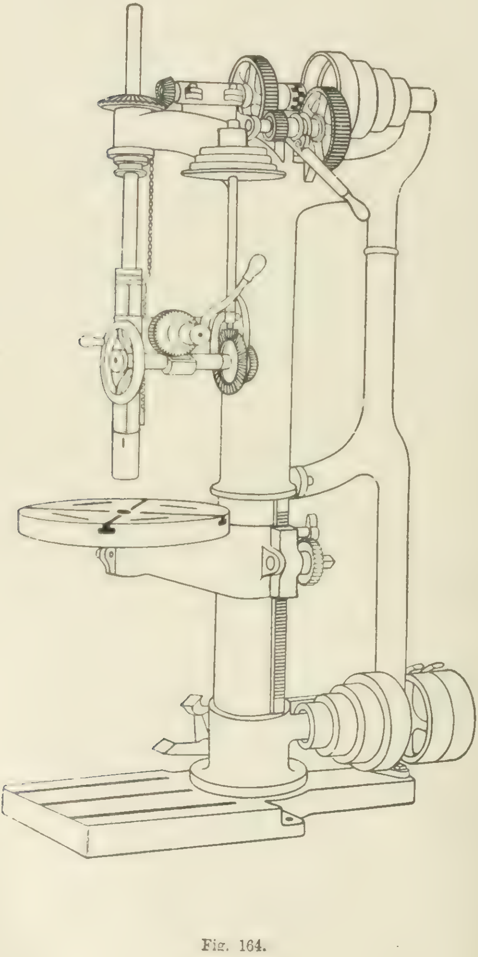


Fig. 164.

While the drill press just described may be taken as representing good practice in the smaller sizes, a different form of construction is often employed in larger tools. A drill press of this class is shown in Fig. 164. Drilling machinery is made both horizontal and vertical. A typical form of the horizontal variety is shown in Fig. 165. These tools are usually of heavier construction and for a larger class of work than the ordinary vertical drill.

Drilling machinery, both horizontal and vertical, is sometimes provided with more than one spindle. In small vertical drills of this description, the spindles are fixed in their relative positions and are not intended to be operated simultaneously: the work is passed from one spindle to another. The true multi-spindle drill is for the purpose of drilling several holes at one time and in any relative position within the limits of adjustment of the machine. Such a drill is shown in Fig. 166.

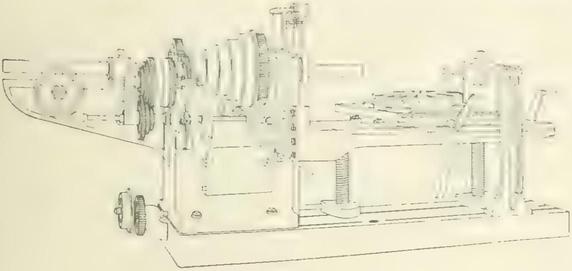


Fig. 165.

The Radial Drill. Another form of drill, known as the radial, is being extensively used. It is shown in Fig. 167.

The drill spindle is carried on the arm A. It is so arranged that it can be set and run at any position on this arm. At the same time, the arm may be swung around and clamped in any vertical or horizontal position about the upright B. These drills are usually employed on heavy work, where a number of holes are to be drilled.

In the case of the drill shown in Fig. 163, the work is ordinarily light, and can be readily shifted so that the position of the holes can be brought beneath the drill. In heavy work, such as engine cylinders, however, this cannot be done. It is, therefore, necessary to be able to shift the drill and place it in a position to do the work. The radial drill affords the means of doing this. When the vertical spindle carrying the drill can be rotated in the vertical plane, holes can be drilled, not only in any position, but also at any angle. Such a drill is called a Universal Radial.

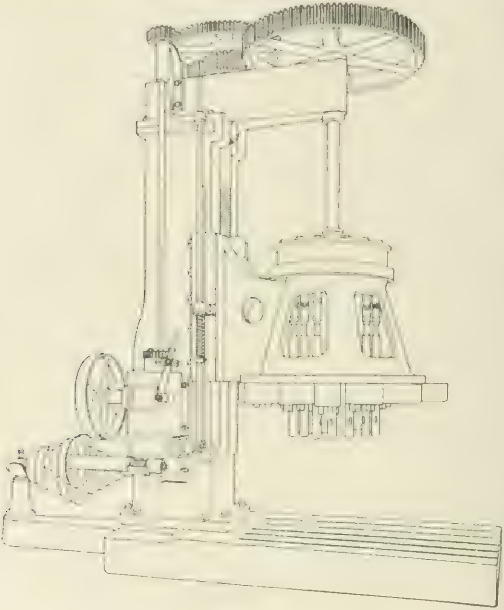


Fig. 166.

The position of the holes is usually laid out for the guidance of the man at the drill. The work is best done as shown in Fig. 168. The center punch mark, indicated by A, shows the location of the center of the hole. The circle upon which the prick punch marks BBBB are placed, gives the location of the circumference of the hole. To drill the hole, place the point of the drill in the center punch mark A, and drill into the metal until the center punch mark has been slightly enlarged, as shown by the circle C, Fig. 168. Then raise the drill and examine the work. If the countersink or hole, whose circumference is indicated by the circle C, is exactly concentric with the outer circle BBBB, then the drill may be put down and the hole drilled

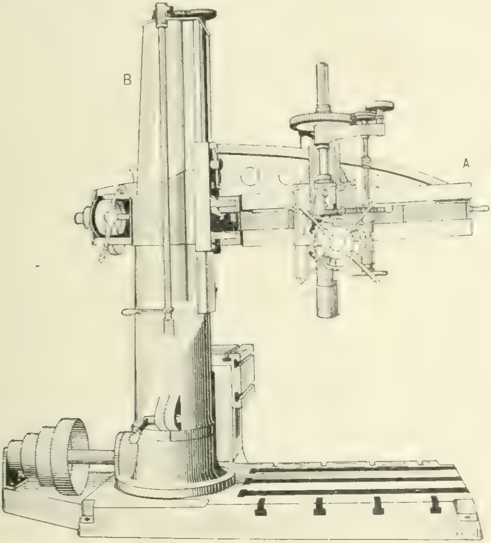


Fig. 167.

Owing, however, to various causes, it is not often that the circle will be concentric. This may be due to an uneven grinding of the drill, a distortion of the metal by the center punch, or an eccentric motion of the drill point, due to a lack of truth in the running of the spindle.

When the countersink is not concentric, the drill must be drawn back to the central position. The method employed is shown in Fig. 169. The round-nosed chisel is used to cut a groove, E, down the side of the countersink, on the side that is farthest from the circle BBBB. The depth of this groove depends upon the amount of eccentricity of the countersink and the depth to which it has been drilled. The drill is then run down again and the groove drilled out. The action of this groove is as follows: as the drill turns, one cutting edge is supported, and is working into the face C, Fig. 170. At the same time the cutting edge is opposite the groove E. The drill, therefore, springs into the groove, as shown. The lip then catches on the edge of the groove and cuts it away, making the hole elliptical, and shifting the center of the drill towards its proper position. As the drill sinks deeper both lips are in contact with the faces C and D, and it has no further tendency to shift.

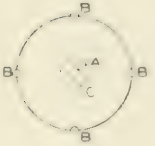


Fig. 168.

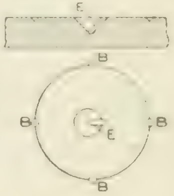


Fig. 169.

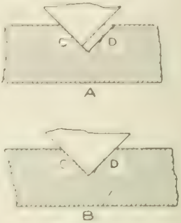


Fig. 170.

When the groove has been drilled out, the drill must be again raised, to ascertain whether or not the countersink is concentric with the outer circle BBBB. If not, another groove must be cut, and the process repeated. If it is, the hole may be drilled. The prick punch marks BBBB are put on the outer circle to indicate its position in case of the obliteration of the line itself.

A twist drill will usually clear its hole of chips. For deep holes this may not occur. It is then necessary to withdraw the drill and clean out the hole. This can be done by a piece of wire bent at the end; also by using a "blowpipe" made of a small tube, and bent to enter the hole, so that the chips will not blow up into the operator's face. Cast iron is more likely to need cleaning than wrought iron or steel. Where flat drills are used, it is always necessary to clean the holes at frequent intervals, as they have no tendency to raise the chips and clear the holes.

A matter to receive due consideration is that the work must be held rigidly on the table while being drilled. This may be done in two ways. If the holes are to be drilled with great accuracy, the work must be clamped to the table. This is often done by means of straps, as shown in Fig. 171. In this figure, a gland A is shown clamped to the table by the straps BB. One end of the strap rests upon the flange of the gland, and the other upon any convenient piece of metal C, of the proper thickness. The bolt D is put up through a hole in the table as close to the work as possible. When the nuts are screwed down, they then put the greatest available pressure on the work and hold it fast. The strap B is made of flat iron. It has one or more holes drilled in it to permit the passage of bolts.

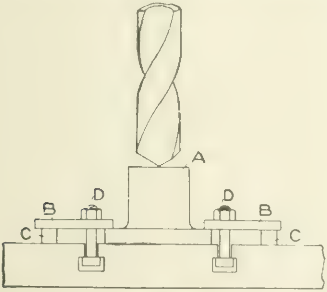


Fig. 171

Another method of holding work in the drill press is by means of a post. This is shown in Fig. 172. It consists of a post A, set loosely in one of the holes in the table. As the drill is forced against the work, it tends to turn the latter with it. When the work strikes the post, it is stopped and held while the hole is drilled. This will not hold the work perfectly steady. It allows the latter to move with the eccentricity of the motion of the drill, but it is in very common use where extreme accuracy is not essential. For example, where a finished bolt is to be used with a driving fit, the work must be securely fastened so that the diameter of the hole may be true. Where a machine bolt made of rough iron is to be used, the hole is drilled $\frac{1}{16}$ inch larger than the normal size of the bolt. Here accuracy is not even attempted; a variation of $\frac{1}{32}$ inch in the diameter of the hole is of no account. Therefore, in such cases, the work may be allowed to merely rest against the post.

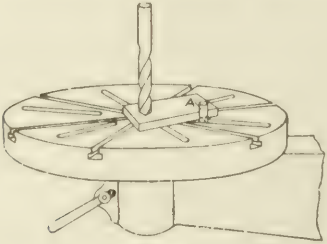
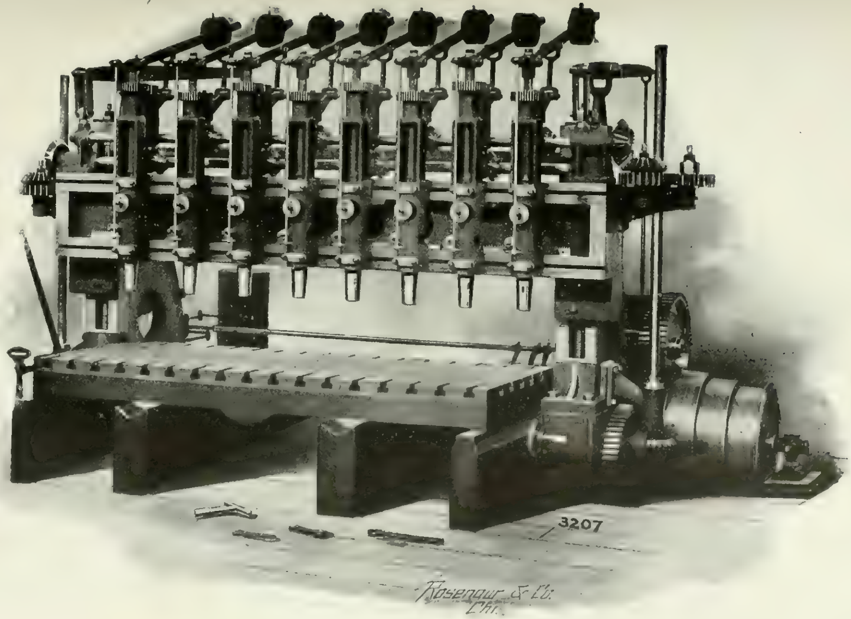


Fig. 172.

This question of holding the work does not apply to drills of the multi-spindle class. It is evident that the tendency of one drill to rotate the work is *counteracted by the action of another drill*. Therefore, no holding devices are needed on drills of more than one spindle.

An angle iron, forming a right angle with the drill table, is used in many cases where the hole cannot be properly located by the use of the table alone. The clamping to the angle iron must be very rigid to resist the pressure of the drill. A tilting table is sometimes used so that holes may be drilled at any required angle. At least one manufacturer is putting on the market a horizontal drilling machine which can drill five sides of a cube at any angle with but one setting of the work.

Drilling machines may also be used for tapping. This requires a reversing device for backing out the tap. The backing-out is done at a much higher speed than the tapping. The tap is held in a friction head that will slip when the tap strikes the bot-



MULTIPLE DRILLING MACHINE.
Niles-Bement-Pond Co.

tom of the hole. The use of collapsing taps, especially on diameters of one inch and over, renders the backing out unnecessary and quickens the operation. Studs may be set by the same device, so that cylinder flanges may be drilled, tapped, and the studs set without removing the work from the drill. Duplicate drilling by means of jigs will be considered later.

THE PLANER.

Next to the lathe, the planer is the most important tool in the machine shop. As the name indicates, it is used for finishing flat surfaces. In the ordinary planer, the work is moved and the tool is at rest. A common form of this tool is shown in Fig. 173. It consists of a bed A upon the upper surface of which suitable guides or ways are planed. The platen B is made to travel back and forth upon these ways. The platen has a rack on its under surface into which the gear C meshes. This gear is driven by a train of gears from the shaft carrying the pulley D. The tool is carried on the tool-head E, where it can be given a slight vertical motion or feed. This tool-head may be fed across the machine by the screw in the cross-rail F. The latter may be raised and lowered by the shaft and gearing shown at the top. This gearing turns two vertical screws running in nuts attached to the cross-rail.

The reciprocating motion of the platen is obtained as follows: the pulleys D and G are driven in opposite direction by belts. Either one may be connected to the shaft on which they turn by a clutch which is operated by the bell crank lever J. On the platen there are two adjustable dogs HH. These are set so that, when the work has just cleared the tool in either direction, one of them will strike against the upper end of the lever I. In the illustration, if the platen is moving in toward the right-hand dog, H will have struck the lever. As the platen continues to move, the lever I is carried to the right and the clutch connection fastening the forward pulley to the shaft broken and that of the return made. The motion is then reversed and continues until the left-hand dog strikes the lever I and again changes the motion.

Ordinarily the tool cuts only when the platen is moving toward the right Fig. 173. As a result of this condition, the platen is made to move more rapidly in the direction of the arrow than in the reverse. This is accomplished by varying the speeds of the pulleys D and G. The usual ratio of the speeds of these pulleys is from 1 to 2, to 1 to 5.

The feed of the tool is accomplished by a friction clutch driving the vertical rack K. This acts only at a point near the end of the travel of the platen. It is so arranged that any vertical or horizontal feed may be given to the tool.

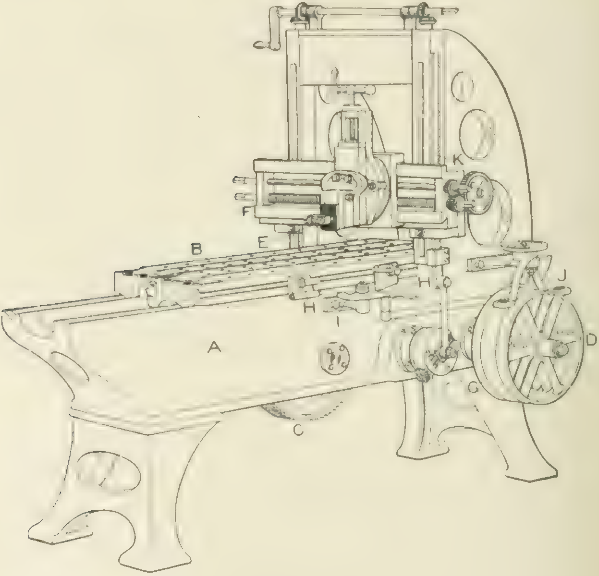
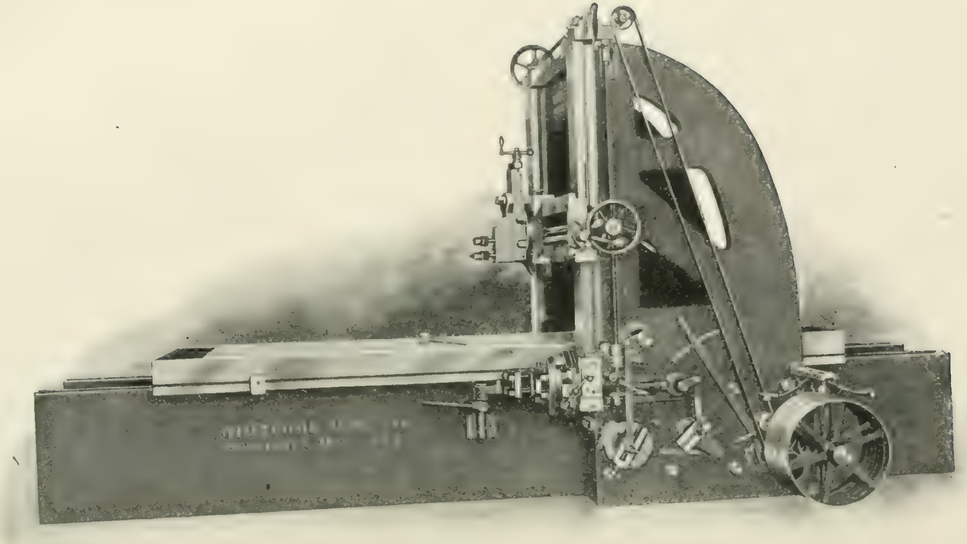


Fig. 173.

Planers are made in a great variety of sizes and styles. Very frequently there are three driving pulleys placed side by side on the same shaft, the central one of the three keyed to the



36' x 36' x 10' PLANER.

Whitcomb Manufacturing Co.

shaft. The reversal of the motion of the platen is obtained by shifting one or the other of the belts onto the central pulley.

Planer Tools. The tools that are used upon planers do not differ essentially from those described for lathe work. The same rule applies regarding the holding of the tool. It should project as short a distance as possible beyond the point of support.

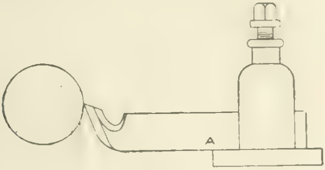


Fig. 174.

When there is an excessive projection, care should be taken that the tool is so set that it will not spring into the work. On the lathe this can be prevented by setting the point of the tool on a line with the center. In Fig. 174 the tool tends to spring and turn about the point A as a center. The dotted line at the point shows how this tends to throw it into the work. The same thing is shown in the planer tool in Fig. 175. This tendency can be overcome by forging the tool so that the cutting point is behind a perpendicular from the point of support, as shown by the dotted lines in Fig. 175. In the latter case the spring of the tool tends to take it out of the work.

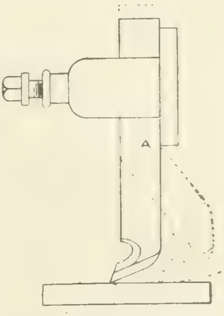


Fig. 175.

Holding the Work. The work is usually held on the planer by clamping it down with straps in a manner similar to that shown in Fig. 171. Where the whole upper surface is to be planed over, holes are sometimes drilled in the sides, into which the rounded ends of straps are set.

It is impossible to give more than general directions for clamping work on a planer. A great variety of blocking, clamps and bolts must be used; such attachments being suited to the work in hand, and requiring an outlay of money which seems to be out of proportion to the appearance of the collection. It should be sufficient to say that the work must be carefully set, strongly clamped and braced to prevent movement by the tool; the clamping should not distort the work. As all castings and forgings change their shape when the surface is removed, it is considered good practice to release the clamps before the finishing cut, in order that the piece may assume its final shape, and then reclamp it without distortion.

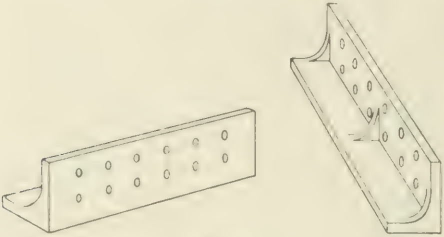


Fig. 176.

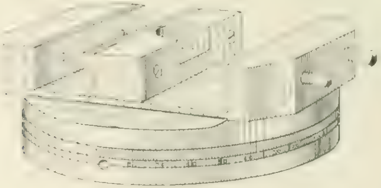


Fig. 177.

Angle irons or knees, as shown in Fig. 176, may be considered as an auxiliary table with a surface at right angles to the main table. Many useful applications of these holding devices will suggest themselves.

Another method of holding work is by using a vise such as is shown in Fig. 177. The body is bolted to the platen and the work is held between the jaws.

Planer centers, as illustrated in Fig. 178, are very useful in machining parts where accurate circular spacing is desired, or where projecting lugs prevent turning in the lathe.

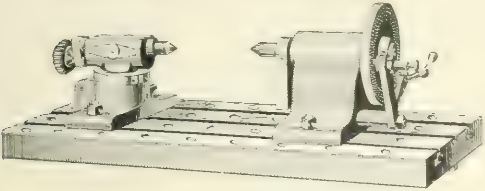


Fig. 178.

The Plate Planer. A special form of planer extensively used in boiler shops and shipyards is the plate planer, Fig. 179. It is used for planing the edges of long plates. The plate is securely fastened between the clamps A and the bed B. The tool is held in the carriage C, which is moved to and fro by the screw D. The screw is driven by the gear H, that meshes with a pinion keyed on the shaft to which the motor is geared. The reversal of motion is obtained by shifting the clutch K. The tappets M for moving the shifting gear are upon the shaft I. They are struck as the carriage approaches the end of its stroke. Unlike the ordinary machine shop planer, the plate planer has no quick return stroke, but has a tilting tool which allows stock to be removed when moving in either direction. Devices of this character have often been tried on regular metal planers, but seem to be satisfactory only when the whole face of the work can be covered at a single stroke of the tool.

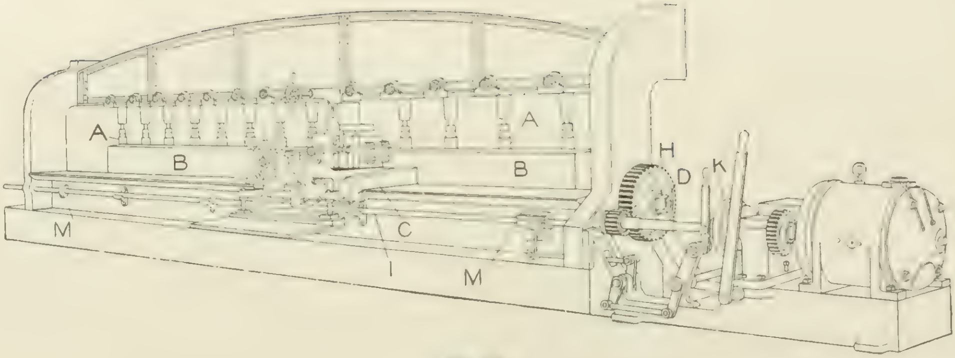
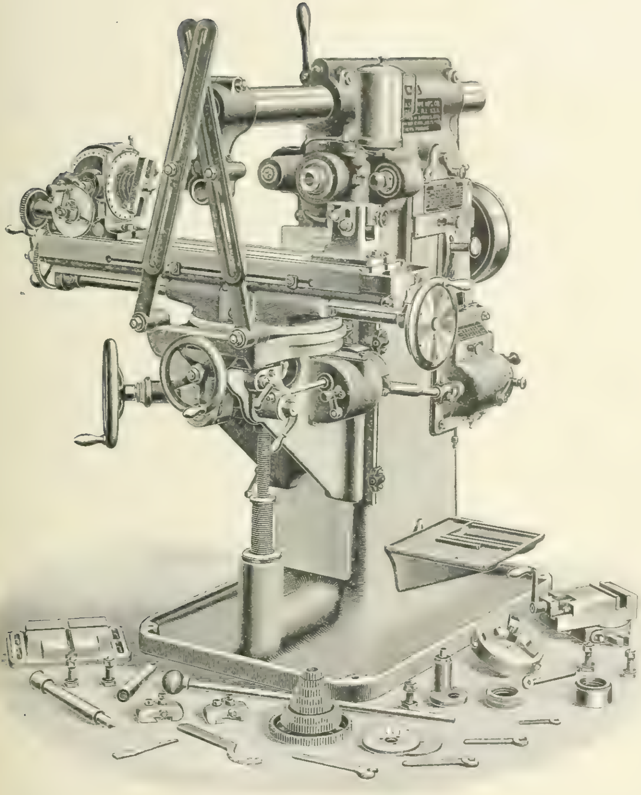


Fig. 129.



UNIVERSAL MILLING MACHINE.

Brown and Sharpe Mfg. Co.

THE SHAPER.

For light work the shaper or shaping planer, Fig. 180, is extensively used. It possesses the advantage of rapidity of action. In this machine, as in the plate planer, the tool moves while the work is at rest. A suitable mechanism causes the ram A to move to and fro. When moving toward the left, the tool is cutting. As in the ordinary planer, the cutting speed is less than the return.

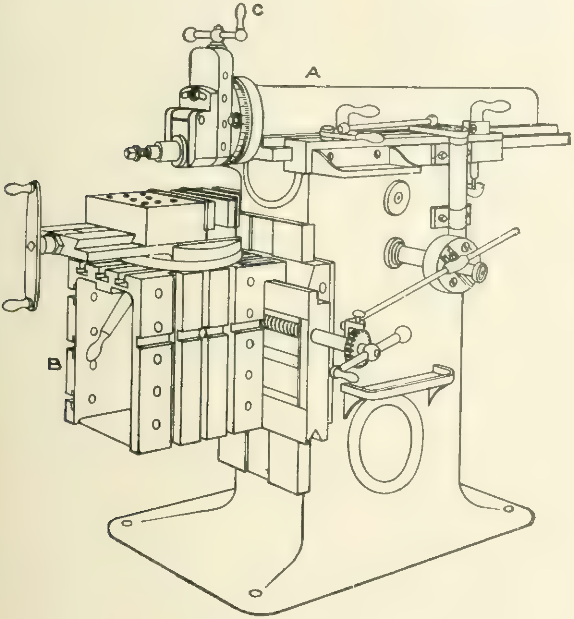


Fig. 180.

The work is held on the table B, which may be adjusted to any convenient height suited to the work to be done. The tool is also allowed a limited vertical adjustment in the slide by turning the handle C. This is the ordinary method of obtaining the vertical feed.

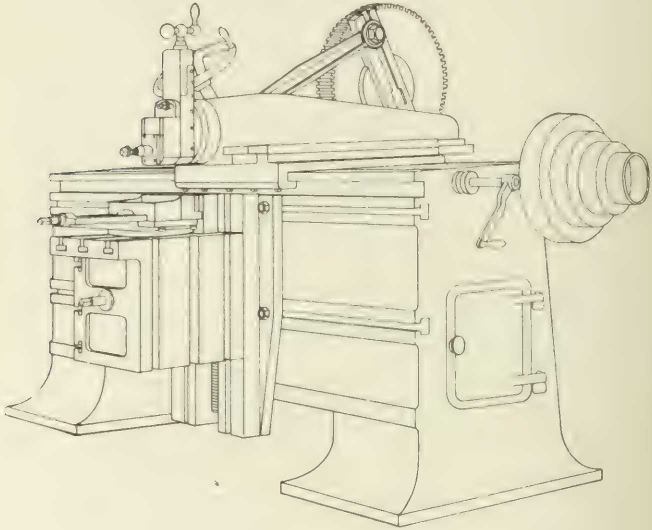


Fig. 181.

The horizontal feed is obtained by moving the table B sidewise. In some shapers it can also be moved vertically to feed to or from the tool; in others the horizontal feed is obtained by causing the tool with the reciprocating parts to move sidewise.

The style of machine shown at Fig. 180 is called the pillar shaper, but where the tool and ram move sidewise it is called the traverse shaper; see Fig. 181. The character of the work done on the shaper and the planer is identical, but as a rule, the shaper is used for the smaller and more delicate parts which could not be handled quickly on the planer. The shaper has the additional advantage of a change of speed which allows small pieces, especially of the softer metals, to be machined at a maximum rate.

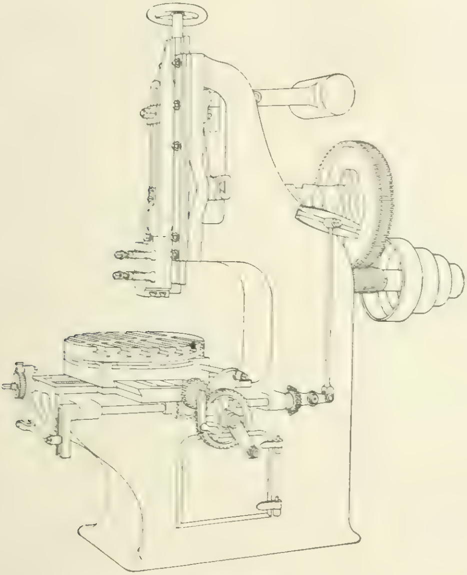


Fig. 182.

Slotter. Another machine tool which is not used as commonly as its many good qualities would seem to warrant is the slotter, Fig. 182. It is, in reality, a shaper with the tool moving vertically instead of horizontally. It is used for working on heavy pieces, and especially in places where an irregular contour is to be formed. The thrust on the tool is vertical, and it must be very stiff. The work done frequently partakes of the nature of the forming of the inside of the hole where the tool must project the whole length of the cut below the bottom of the head. Such a case is that of the slotting of locomotive frames. The best type of tool for such a class of work is a strong bar, as shown in Fig. 183. The bar is held in the head of the tool just as any tool would be. Near the lower end it carries the cutting tool, which may be fastened by a set-screw or wedge. Such a tool should always be used when it is possible. It has the advantage of being stiffer and less likely to spring than a forged tool.

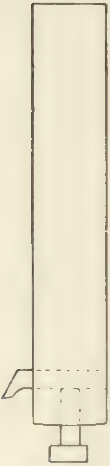


Fig. 183.

The tool used in a slotting machine differs from that used in the lathe or planer in that the direction of the cutting motion is different. Fig. 184 illustrates a slotting tool to be used for doing such work as the cutting of keyways in the hubs of pulleys. It will be seen that if the tool is moved in the direction of the arrow, the face B becomes the one against which the chip bears. It, therefore, corresponds to the top of the lathe tool. The sharper the slope given to the face B, the keener the edge, just as increasing the rake of the lathe tool increases its sharpness. The face A must also be cut away as indicated. This corresponds to the clearance of the lathe or planer tool. It is quite possible, at times, to give these tools a larger amount of rake. Such a form

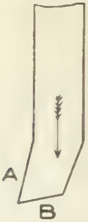


Fig. 184.

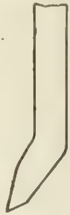
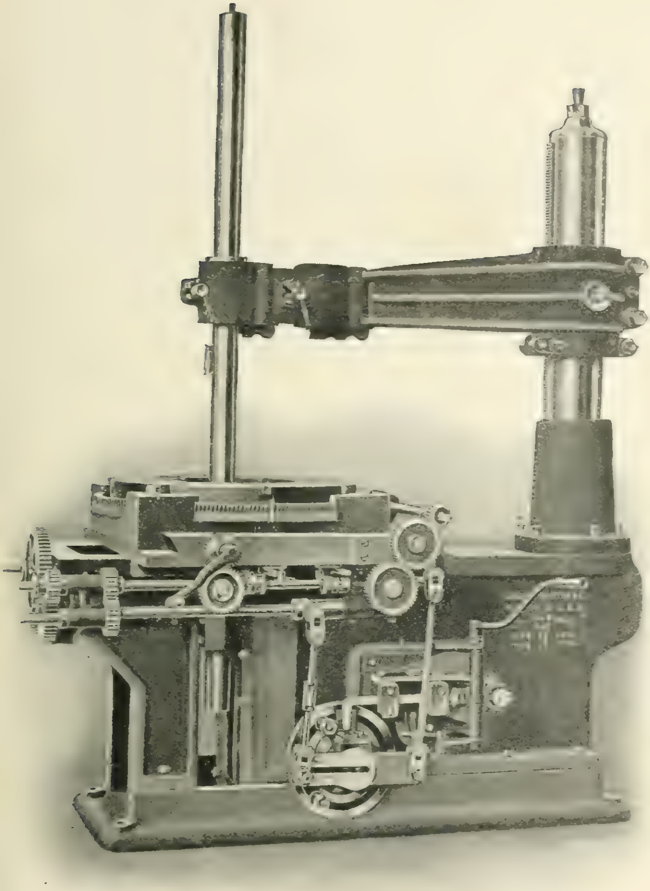
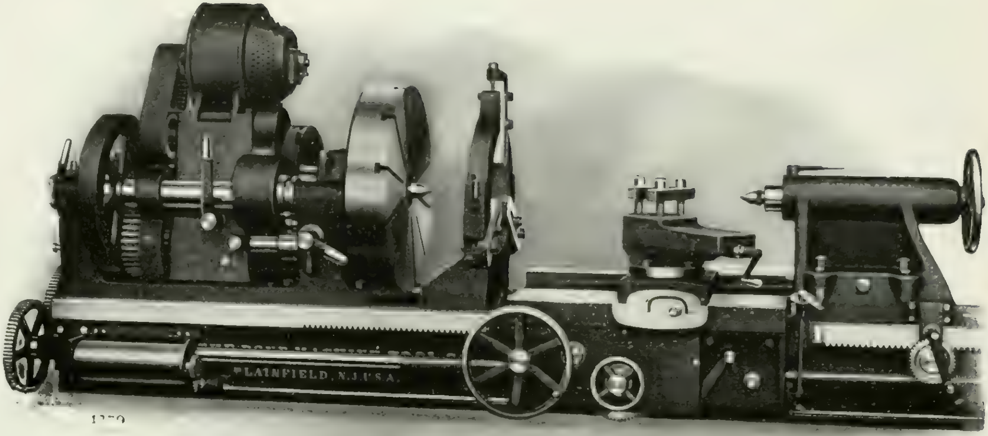


Fig. 185.



DRAW STROKE SLOTTER.
Baker Brothers.

is shown in Fig. 185. The shape of this tool is such that it is very strong in the direction of the thrust, besides having a keen cutting edge.



42-INCH POND LATHE.
Niles-Bement-Pond Company.

MACHINE SHOP WORK.

PART III.

THE MILLING MACHINE.

The operation known as milling differs so radically from the removal of metal by methods previously described, that it merits much more careful and lengthy discussion than has been devoted to the other methods. Due, also, to its increasing importance and general use, it calls for a somewhat extended discussion. While milling is coming rapidly into favor as a means of doing work which has formerly been done on the shaper and planer, it does not follow that the shaper and planer are to be entirely abandoned. There has been a tendency during the past few years to belittle the planer and shaper in favor of the milling machine. This tendency is not warranted even by the rapid and economical method of milling. There is a large class of work which can be done accurately only by means of a single-pointed tool such as is used in the planer and shaper.

The fundamental difference between planing and milling lies in the character of the tool employed. The planer uses a fixed single-pointed tool with a reciprocating motion either of the tool or the work, while milling is performed by the use of a rotary tool with several cutting points, of which the circular saw is a familiar example. This rotary multiple cutter is the basis of all milling operations, and, as the saw may be taken as a good example of such a cutter, so the work done by the circular saw in cutting metal may be said to be an example of milling. The ordinary milling cutter is nothing more than a saw in which the contour of the cutting blades is made to suit the work in hand.

Circular saws for use upon metal have been, and still are, often mounted in a hand lathe, Fig. 186. The saw is held on an arbor between centers, and the work placed on a table rest, which takes the place of the T-rest used in ordinary hand turning. Here is an example of milling in its most primitive form; the work being fed to the saw by hand, with no guides or positive movements. It was an easy matter to provide guides on the table rest for the work, and the next real important step was to use an engine lathe in place of the hand lathe. Here the saw was mounted as before, the work clamped to the carriage by suitable fixtures and fed positively to the saw, both as to direction and amount.

It was but a step to make a saw wide enough to cover a considerable surface, or to have a thick saw with a suitably formed cutting edge. Several saws of different shapes and sizes can be mounted in a gang on an arbor and perform operations which it would be hard to duplicate on the shaper or planer. Even in the present age of special machines for milling, a great deal of work of this character is still performed in the engine lathe by the method indicated.

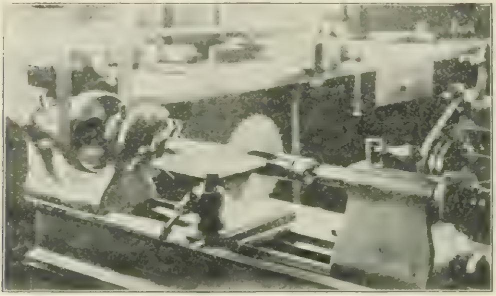


Fig. 186.

It is evident that one of the great advantages of milling is the certainty of exact duplication, a feature of prime importance in the manufacture of interchangeable work.

Of course, it was not to be expected that such an important operation as milling could be intrusted to a machine like the lathe, which was primarily intended for an entirely different, but equally important, class of work.

About the first machine built exclusively for milling was the so-called Lincoln miller, Fig. 187, which consists essentially of a bed carrying the equivalent of the head stock and tail stock of a lathe, with means for rotating the cutter arbor, which is carried directly by the head stock spindle, and steadied and supported by the tail stock. There is also provided a table upon which the work can be fastened either directly, or by means of a vise, and an automatic feed across the machine at right angles to, and below, the cutter arbor. This is simply the milling attachment in the lathe transferred to a machine designed to do nothing but milling.

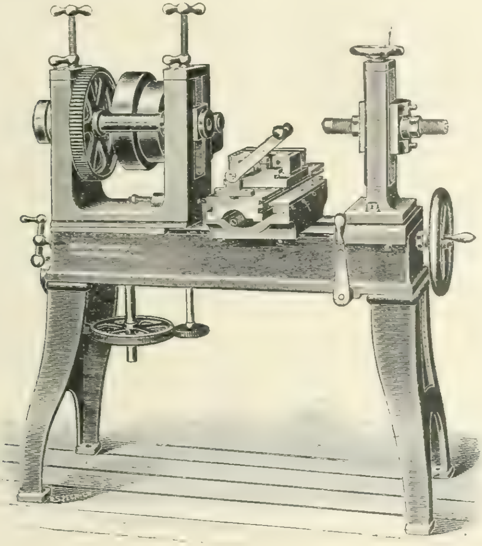


Fig. 187.

The elementary cutters designed to be used on this type of machine are of the form already described, viz.: of the saw type.

As the **types of cutters** used determines, in a large measure, the design of the machines themselves, it will be better at this point to take up a description of some of the different cutters, in order that the adaptation of the machine to the cutter may be clearly seen.

Screw slotting cutters, Fig. 188, and slitting saws, Fig. 189, are indentical with the saws which, we have already seen, were employed in the lathe. The true milling cutter, Fig. 190, has a face much wider in proportion to its diameter than the common

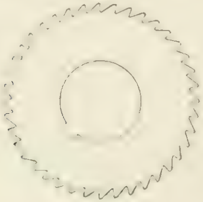


Fig. 188

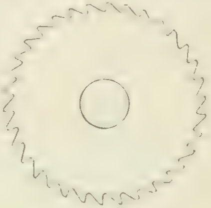


Fig. 189

saw. It is for the production of surfaces, rather than for a thin cut or kerf for separating pieces of metal. These plain cutters are made in a large number of diameters and lengths, and are all **designed for the generation of plane surfaces.**

As we have seen in the case of reamers, heavy cuts can be taken more easily when the chip is broken up into small pieces

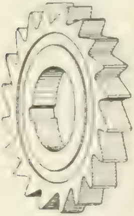


Fig. 190

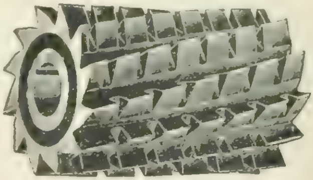


Fig. 191.

therefore in milling cutters designed for roughing, it is customary to nick the teeth, see Fig. 191, in such a way that the space left by one tooth may be taken out by the following tooth. This makes the cutting easier. A plain cutter of any considerable length will not make a smooth surface because of the varying pressure of the cutter, as one tooth after another leaves the work. To avoid this springing tendency, cutters are made with **spiral teeth,** Fig. 192, either right or left hand, so that there is practically a uniform distribution of pressure at all points during the cut.

When it is desired to mill the side of a piece, it is necessary that there should be teeth on the side of the cutter. Such cutters are usually made comparatively narrow and with teeth on both sides, as shown in Fig. 193. These **side milling cutters** are usually sold in pairs, as they can be mounted together and thus mill off both sides of a piece of work, similar to a bolt head, and are, therefore, called heading or straddle mills.

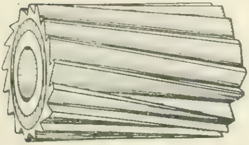


Fig. 192.

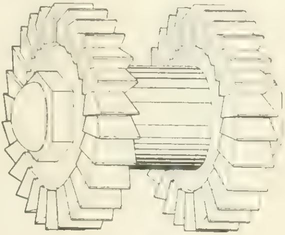


Fig. 193.

If two cutters of the same diameter are mounted together, it is difficult to mill a surface which will not show the point of separation of the cutters. This can be avoided by making the ends of the cutters, where they come together, of such a shape that they interlock one with the other. This feature of interlocking, see Fig. 194, is especially valuable when cutting slots which must be of a definite width. An ordinary cutter will wear away by use, or by grinding, and thus lose its correct size. The thickness of interlocking cutters can be maintained by means of very thin washers, and, due to the interlocking of the cutters, will not show that any space exists between them.

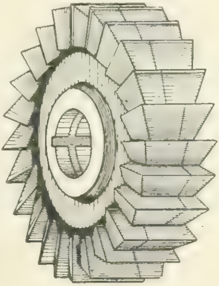


Fig. 194.

Cutters may be mounted in **gangs** of great variety and combination, a typical one being shown in Fig. 195. These cutters may be of any desired form, and can be made to produce a variety of shapes. The so-called angle cutters, Fig. 196, are employed in the manufacture of cutters, and, when making spiral cutters, must have an angle on both sides. The customary angle in such cases being 40° on one side and 12° on the other. The other common single angle cutters vary from 40° to 80°, either right or left hand. Double angle cutters can be had with either 45°, 60°, or 90°, included angle.

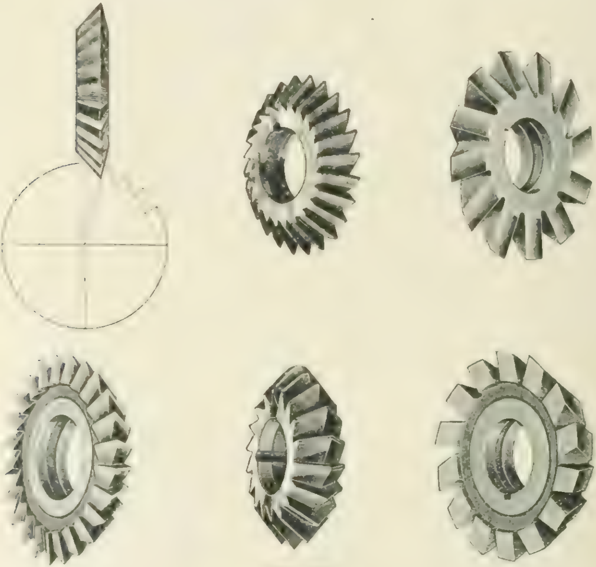


Fig. 196

We have considered up to the present time, only such cutters as are made from a single piece of steel. In large cutters, however, the cost of the steel becomes an important item, and there is danger of losing a large amount of labor through accidents in hardening. To make a cheap serviceable cutter of large size, it is customary to use a cast-iron body with inserted steel teeth. There are several different methods of holding these teeth. Usually, when the inserted tooth is in the form of a blade, they are held by taper pins or screws, Fig. 197. These blades are renewable, the cast-iron body being used many times. A cheaper, permanent cutter can be made by casting the body around the teeth, thus making a very rigid support for the blades.

Another form of **inserted-tooth cutter** consists of round hardened steel pins driven into holes in a cast-iron body. This cutter is also permanent in form, Fig. 198, as broken teeth cannot be replaced, and, when the teeth are worn almost down to the body, the whole cutter is thrown away.

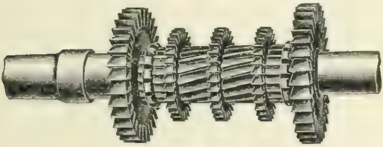


Fig. 195.

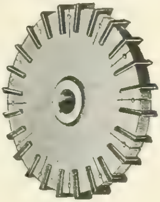


Fig. 197.

Brief mention has been made of cutters to generate irregular contours. These cutters are known as **formed cutters**, and, except in certain shapes, such as quarter and half rounds, are not carried in stock, but are made only to order. There is such a large variety of forms for which such cutters may be used, that it is impossible to give more than a typical example. The form shown, Fig. 199, consists in reality of several cutters, some of them of ordinary

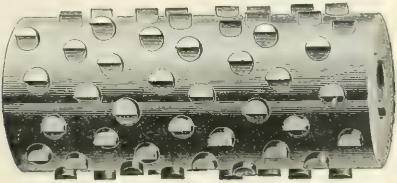
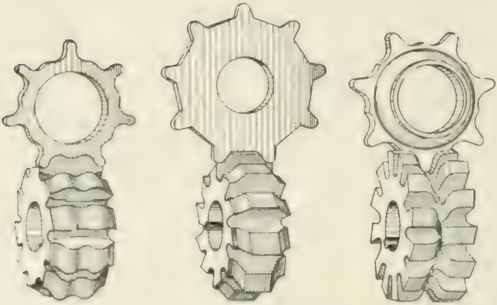
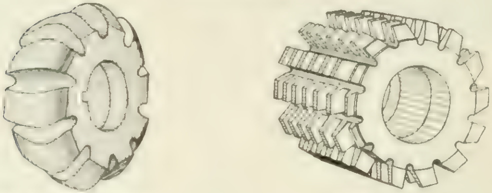


Fig. 198.

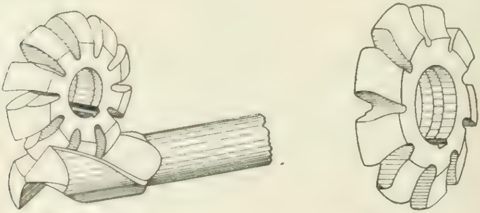


Sprocket Cutter



Tapered Reamer Cutter

Worm Gear Hob



Twist Drill Cutter

Gear Tooth Cutter

Fig. 200.

shapes and sizes, with others of special forms, the whole making a gang cutter whose object is very apparent.

Among the standard shapes of formed cutters are some which are now carried in stock for producing certain tools which require cutters of definite yet peculiar form. Among these may be mentioned cutters for fluting taps, reamers, and twist drills, cutters for sprocket and gear teeth, and cutters, known as hobs, for the production of worm gears. See Fig. 200.

End Mills. All the cutters thus far mentioned are provided with central holes, and are intended to be mounted on an arbor which is carried by the spindle and supported in some suitable manner at the outboard end. There is an entirely different class of cutters, however, which are supported by the spindle only, and are provided with teeth on the end of the cutter. These are known as end mills. They are made in a great variety of shapes and sizes, the ordinary end mill, Fig. 301, being cylindrical, with either a right or left-hand spiral.

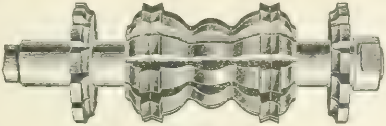


Fig. 199.

A special form of end mill for making T-slots is called the T-slot cutter, and is, in reality, a small side milling cutter carried by a small central stud, see Fig. 202. Dovetail cutters, and cutters of various angles for making ratchets, are merely variations of the end mill.

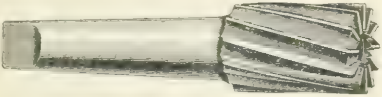
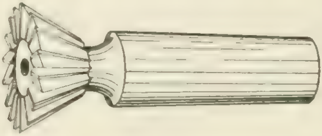


Fig. 201.

When end mills are made of large size, they can be furnished with inserted teeth similar to those used on cutters for the arbor. See Fig. 203. The heaviest end mills for the milling machine are sometimes made as large as fifteen to twenty inches in diameter, the cast-iron body being screwed directly on the nose of the spindle, making a very powerful and fast-cutting tool.

The plain milling cutter is mounted on an arbor in a way very similar to that in which its prototype, the circular saw, was mounted. For use in the lathe, this is usually centered at both ends and driven by a dog. When used in a regular milling machine, the arbor, Fig. 204, is fitted with a heavy taper shank with a tongue at the end for driving, and washers of varying thickness, so that cutters of different widths may be used on the arbor, and, to suit the position of the work, in different positions on the same arbor. The washers and the cutter must have absolutely parallel faces. Otherwise, when the nut at the end of the arbor is tightened, there will be springing of the arbor due to the irregularity in thickness. The outboard end of the arbor is provided with a center or straight pin to be steadied by the over-



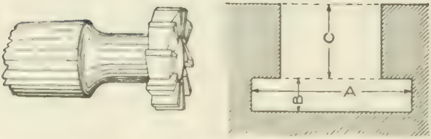


Fig. 202.

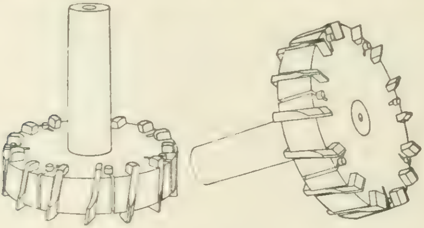


Fig. 203.

hanging arm, and the nut on the arbor should not be tightened until this arm is in position, as there is danger of springing the arbor by the leverage of the wrench.

Where the cutter teeth are formed integral with, or fastened to, the taper shank, as in the case of end mills, the shank, if it be of a proper size, is forced directly into the taper hole in the spindle. In many cases, however, the taper shank of the cutter is much too small to fit the spindle hole, and taper collets, Fig. 205, are used to bush down the spindle hole to the proper size. Of course, it is necessary that the axes of the outer and inner tapers should coincide, otherwise the cutter will not run true. In some cases it is necessary to use two collets, one within the other, before introducing the cutter shank.

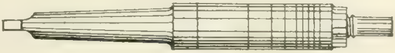


Fig. 204.

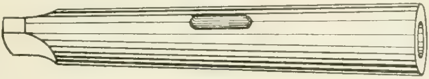


Fig. 205.

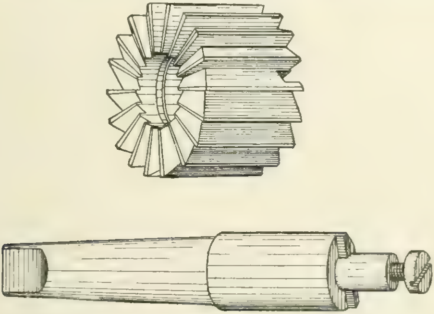


Fig. 206.

When **shell end mills**, Fig. 206, are used, a special form of taper shank is employed which can take several different sizes of cutters. The construction is so obvious from the illustration that explanation is unnecessary.

End mills, held on taper shanks, rely on the friction of the taper for holding in position, although being driven by a tongue at the end of the shank. Therefore, cutters of this description should not have a spiral in a direction which would tend to pull the cutter out. This is not a serious objection when using the cylindrical portion of the cutter, but, when using the end of the cutter, it means that the teeth can have no rake and must scrape, rather than cut the work. In order to use a leading spiral on the cutter, the shank must be held positively in the spindle. This usually is accomplished by inserting in a threaded hole at the rear end of the shank, a rod which extends through the hollow spindle and brings up against a collar on the outside. This can be set up solidly, and all danger of loosening up of the cutter shank will be avoided.

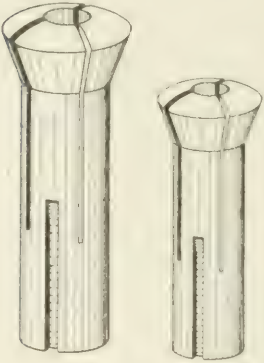


Fig. 207.

When the cutter is small, as compared with the diameter of the spindle taper, a screw collet may be used, as the friction of the collet will be greater than the tendency of the leading spiral to move the cutter from the spindle. Again, these screw collets are commonly made of machine steel, while the end mills are made from tool steel. The short, steep taper and threaded end are shorter than the long taper shank, and therefore make a cheaper cutter.

One of the best means for holding small end mills is by the use of spring collets, Fig. 207, which can firmly grasp the straight shank of the cutter. When cutters are to be changed frequently, this is a particularly satisfactory method, although it will not answer for roughing cuts with cutters of large diameter.

An ordinary drill chuck can be held in the spindle by mean of a taper shank, and furnish a means of holding straight shank drills and other small straight-shank tools.

A very convenient method of holding certain tools consists in fitting a three-jawed universal lathe chuck to the threaded nose of the spindle, thus enabling straight-shank tools of large size to be held firmly and accurately. Cutters of any kind are rarely held in chucks on the milling machine, but a large number of other small tools can be thus fastened to very great advantage.

In taking up the subject of machines devoted especially to milling, it is well to consider that the transition from milling in the lathe to the special milling machine, is bridged by an attachment to the lathe by which the functions of the milling machine were well served. This is especially noticeable in milling attachments attached to bench lathes, Fig. 208, said attachment being mounted on a foot connected with the end of the bed, and the head stock turned around on the bed to serve as a spindle for the milling attachment. This temporary arrangement, which is still used as a combination in some cases, led to the introduction of the **bench miller,** Fig. 209, which was naturally intended for small work only, and therefore is not provided with automatic feeds, hand feeding by means of levers being used.

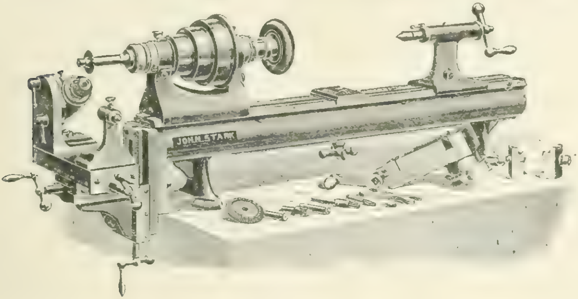


Fig. 208.

As this bench milling machine comprises all the essential elements of the more elaborate machines, it will be well to call attention to the principal parts of the machine and their functions.

The horizontal milling machine consists of a frame or box structure carrying a horrizontal spindle in the upper portion, together with brackets or an overhanging arm to steady the spindle. The front of the machine is carefully scraped at right angles to the spindle, and there is mounted thereon a knee, its upper surface being parallel to the spindle in the horizontal plane and capable of movement in a vertical direction. This knee carries what is known as the saddle, the upper portion of which is also parallel to the spindle. The movement of the saddle is towards and from the frame of the machine, and therefore parallel to the spindle. The saddle, in turn, carries the table to which the work is attached by means which will be described. The upper surface of the table is parallel to the spindle, and the table movement is at right angles to the spindle in the horizontal plane.

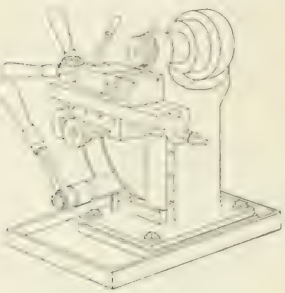


Fig. 209

The combination of these three motions, at right angles to the spindle in the vertical plane, parallel to the spindle in the horizontal plane, and at right-angles to the spindle in the horizontal plane, give to the milling machine what is known as its range. It allows any portion of the table to be brought under the cutter at any distance covered by the vertical feed.

Among the principal advantages of the milling machine, are the wide range of working capacity and the accuracy with which the table can be placed with relation to the cutter. This accuracy is obtained by means of graduated dials on the feed screws, which are read directly to .001 inch, and, by estimation, to .00025 inch. For many years the milling machine was the only tool which supplied these **micrometer graduations,** but they are now being applied to nearly every class of machine tool in which accurate adjustment is necessary. A very common method of graduation is by the use of a screw with a pitch of $\frac{1}{5}$ inch and 200 graduations on its dial. In some cases, a screw with a pitch of $\frac{1}{4}$ inch is used with 250 graduations, but it is always safe to assume that the single graduation on a milling machine means a movement of .001 inch.

Lost motion or backlash between the screw and its nut in any of these adjustments is the cause of frequent error and should never be neglected. Even in a machine in excellent condition, when the motion of the screw is reversed, it will turn through an angle giving the equivalent of about .005 inch movement of the part being fed along, but with no actual movement of the part. As an example, if, in moving the table from the column, the operator carries it .003 inch too far, it will not suffice to simply turn the dial back three graduations. The table should be brought back several hundredths of an inch, and then advanced to within .003 inch of its former position. In order to facilitate the quick and accurate

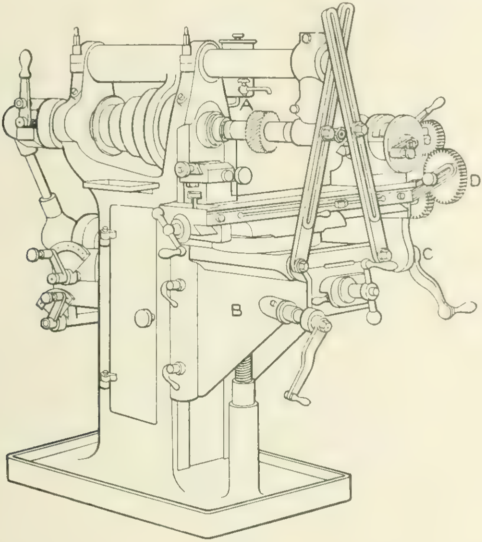


Fig. 210.

reading of these dials, they are arranged so that they can be readily set to zero whenever desired.

The movements above described for the adjustment of the work are those necessary for what is termed a plain milling machine. In order to have a **universal milling machine,** Fig. 210, it is necessary that the table be so arranged that it can be swung upon the saddle in the horizontal plane, so that its feeding movement is not at right angles to the axis of the spindle. Universal milling machines usually have a total angular movement of 90°, 45° on either side of the normal position.

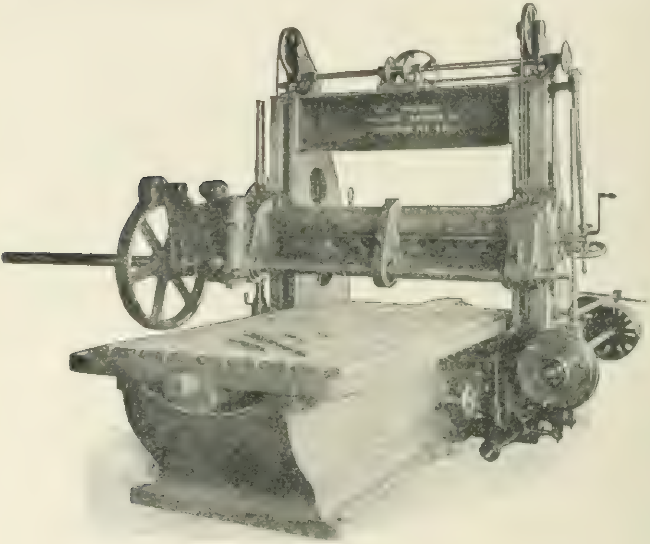
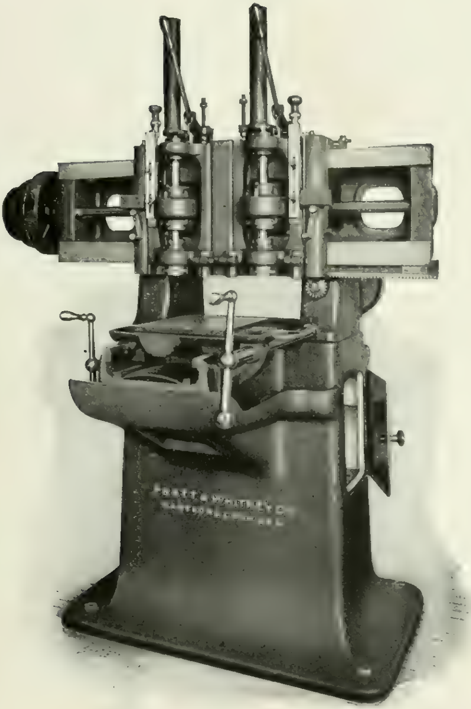


Fig. 211.

While the milling machine developed from the lathe through the Lincoln miller to the standard horizontal universal machine, its development, for work on which heavy cuts are necessary, took an opposite course.



TWO-SPINDLE PROFILING MACHINE.
Pratt and Whitney Co.

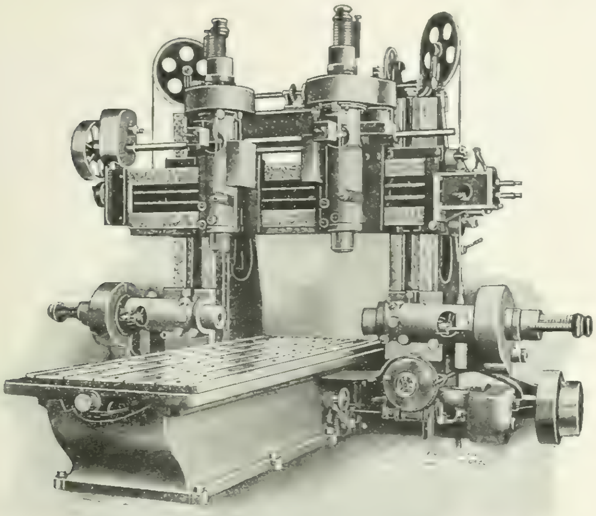


Fig. 212.

The slabbing miller, Fig. 211, is of the planer type, the cross rail carrying a rigidly supported cutter, while the table has the comparatively slow feed required for milling. This type of machine is especially valuable where broad surfaces are to be machined on pieces of work which are of such shape that they can be readily and uniformly supported to withstand the cut.

In order to produce true work by heavy milling, it is not only necessary that the work shall be supported as already outlined, but also, that the cut be nearly uniform in depth and width. If the section of the cut varies greatly, or, even with uniform cut, if the work is irregularly supported, the metal will spring under the influence of the cutter and it will be found that the work is not true. Therefore, work of a character that is liable to be distorted by the process of milling, may easily be performed to better advantage by the process of planing.

As the planer is sometimes furnished with more than one head, so these heavy milling machines are often furnished with more than one spindle. Two vertical heads on the rail and a facing head on each upright, Fig. 212, makes a machine capable of removing a large amount of metal, if the work is of such a character as to stand up under the cut.

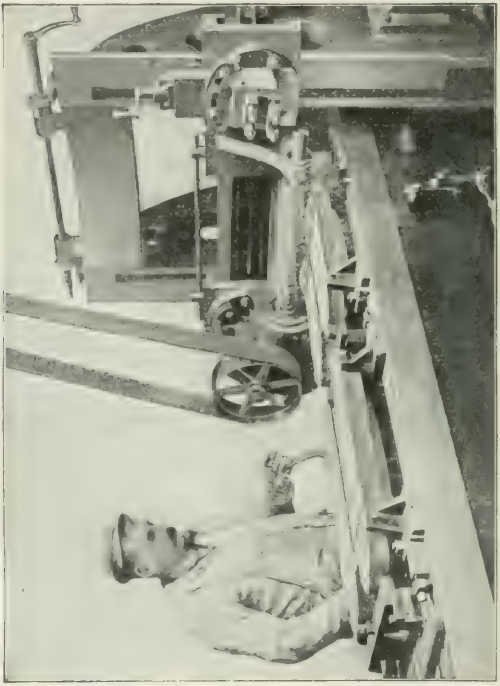


Fig. 213.

It is often desirable, from the point of view of economy of time, to combine the operations of milling and planing, and, with this end in view, milling attachments are made for the planer, Fig. 213, and attached to the cross rail. The changes required from the planer drive, are an extra belt to rotate the cutter and a special countershaft to slow down the movement of the table. This attachment can carry a slabbing, gang, or formed cutter on an arbor for horizontal milling, or it can carry end mills, Fig. 214, by turning the head through 90°, thus bringing the spindle to a vertical position. This last arrangement of the spindle is of great utility, as it allows cutters to reach down into places which would be inaccessible by any other means.

The advantages of the **vertical milling spindle** are so evident, that nearly all makers of horizontal machines furnish what is called a vertical head, Fig. 215. This vertical head is very rigidly supported on the column, and by means of the overhanging arm, so that cuts can be taken of as great depth as with the horizontal spindle. The vertical spindle can also be turned in the vertical plane, so that an end mill can be used at any angle with the table.

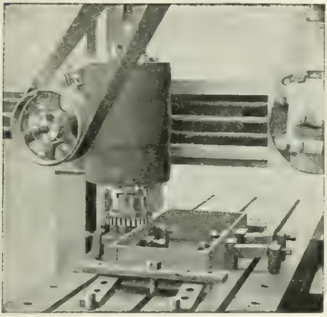


Fig. 214.

There are several machines made in which the vertical spindle alone is employed, Fig. 216, there being no provision for a horizontal spindle.

Such machines are provided with the feed motions of the horizontal type, and also with a rotating table by which circular work can be done. A large amount of work formerly done in lathes is now being done in vertical spindle machines, as well as many pieces formerly machined on planers and shapers.

The duplex milling machine, Fig. 217, has both the horizontal and vertical spindles combined in one, which allows the spindle to be placed at any angle from horizontal to vertical, and combines all the good points of both machines. The head of the duplex miller can be moved out over the table in such a way as to greatly increase the range of the machine, and this head is also provided with a drilling attachment whereby holes may be drilled at any angle. Attention is called to the rope drive on this machine by means of a twisted rawhide belt or rope. This makes a very smooth and quiet drive.

In order to accommodate different sizes of cutters, maintain a uniform cutting speed, and also to allow for difference in hardness of the material being worked, it is necessary that the milling machine should be supplied with several speeds. In the ordinary miller we usually have a four-step cone with back gears, which gives eight speeds with a single overhead belt. The countershafts for these machines are of the friction type, and are supplied with two driving pulleys in order that the machine may be driven in either direction. But, if the reverse motion is not desired, there can be two pulleys driving in the same direction, but at different speeds, giving a total, including the back gears, of sixteen speeds for each machine. The speed used on any particular work depends, as before stated, on the diameter of the cutter and the character of the work. Thus, with carbon steel cutters, the cutting speed will be 30 to 60 feet per minute. With high-speed steel cutters, nearly double these speeds may be maintained, if the drive of the machine is strong enough to pull the cut.

Fig. [illegible]

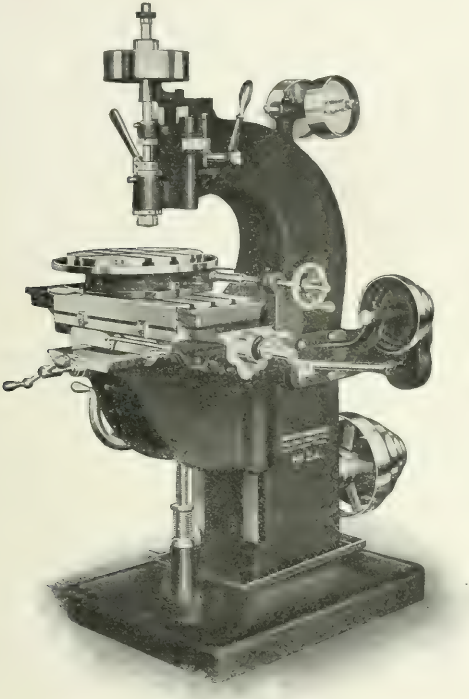


Fig. 216.

When using very small cutters, the machine itself will not give a speed which is high enough to suit the diameter of the cutter. For such work, a high-speed attachment, Fig. 218, is furnished, by which the small, light cutters may be driven at a suitable rate.

Of equal importance with the correct speed for the cutter, is the maximum feed or table speed, which is reckoned in inches per minute. A more logical method of designating the feeds, and one which has been adopted by several makers, is to give the advance of the table in thousandths of an inch for every turn of the spindle.

Based upon the use of the ordinary carbon steel cutters, The Brown & Sharpe Co. have prepared the following statement regarding the speed of mills: "It is impossible to give definite rules for the speed and feed of mills. The judgment of the foreman or man in charge of the machine should determine what is best in each instance.

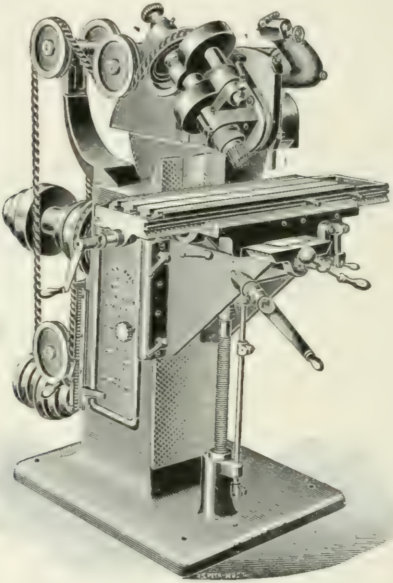


Fig. 217.

"As usually the highest possible speed and feed are desirable, it pays to increase them both until it is seen that something will break or burn, and then reduce to a speed and feed of safety. Sometimes the speed must be reduced, and yet the feed need not be changed.

"The average speed on wrought iron and annealed steel is, perhaps, 40 feet per minute, which gives about sixty turns per minute with mills $2\frac{1}{2}''$ in diameter. The feed of the work for this surface speed of the mill can be about $1\frac{1}{2}''$ per minute, and the depth of the cut about $\frac{1}{16}''$. In cast iron, a mill can have a surface speed of about 50 feet a minute, while the feed is $1\frac{1}{2}''$ per minute and the cut $\frac{3}{16}''$ deep. In tough brass, the speed may be 80 feet, the feed the same as in cast iron, and the chip $\frac{3}{32}''$.

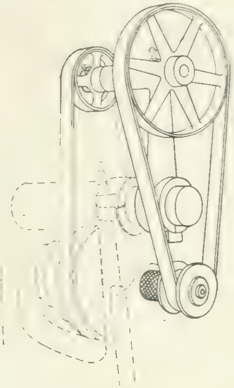


Fig. 218.

"As small mills cut faster than large ones, an end mill, for example, $\frac{1}{2}''$ in diameter, can be run about 400 revolutions per minute with a feed of 4″."

Addy, an English authority, gives as a safe speed for cutters of 6″ diameter and upwards:

Steel, 36 ft. per minute with a feed of $\frac{1}{2}''$ per minute.
Wrought Iron, 48 ft. per minute with a feed of 1″ per minute.
Cast Iron, 60 ft. per minute with a feed of $1\frac{2}{3}''$ per minute.
Brass, 120 feet per minute with a feed of $2\frac{2}{3}''$ per minute.

He also gives a simple rule for obtaining the speed: The number of revolutions which the cutter should make when working on cast iron = 240 divided by the diameter in inches.

The following table has been prepared by Messrs. Brown and Sharpe to give the speed, feed, and depth of cut that can be obtained with a machine similar to that illustrated in Fig. 210.

SURFACE MILLING OF CAST IRON.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of Cast Iron in Inches.	Under Scale of Cast Iron in Inches.
3	42	34	$\frac{1}{16}$	1	$6\frac{7}{8}$	$8\frac{7}{8}$
	42	34	$\frac{1}{2}$	1	$4\frac{1}{8}$	$6\frac{1}{2}$
	42	34	$\frac{1}{16}$	2	$6\frac{5}{8}$	$8\frac{7}{8}$
	42	34	$\frac{1}{2}$	2	$2\frac{1}{2}$	$4\frac{1}{8}$
	42	34	$\frac{1}{16}$	3	$6\frac{5}{8}$	$8\frac{5}{8}$
	42	34	$\frac{7}{16}$	3	$1\frac{3}{8}$	$2\frac{3}{16}$
$3\frac{1}{2}$	42	40	$\frac{5}{32}$	3	$4\frac{1}{8}$	$6\frac{1}{4}$
	42	40	$\frac{1}{8}$	$3\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{1}{2}$
$4\frac{1}{2}$	42	50	1	2	$4\frac{1}{8}$	$6\frac{1}{2}$
	42	50	1	4	$3\frac{1}{2}$	$4\frac{1}{8}$
	42	50	1	6	2	$2\frac{1}{4}$
	42	50	$\frac{1}{8}$	6	$4\frac{1}{8}$	$6\frac{1}{2}$
	42	50	$\frac{11}{32}$	12	$1\frac{3}{8}$	2

SURFACE MILLING OF SOFT MACHINERY STEEL.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of S. M. S. in Inches.	Under Scale of S. M. S. in Inches.
3	38	30	$\frac{1}{16}$	1	6	8
	38	30	$\frac{1}{2}$	1	$1\frac{1}{8}$	$1\frac{7}{8}$
	38	30	$\frac{1}{16}$	2	$2\frac{3}{8}$	$3\frac{1}{2}$
	38	30	$\frac{1}{2}$	2	$\frac{3}{4}$	$1\frac{1}{8}$
	38	30	$\frac{1}{16}$	3	$1\frac{1}{8}$	$1\frac{7}{8}$
	38	30	$\frac{3}{8}$	3	$\frac{3}{4}$	$1\frac{1}{8}$
$3\frac{1}{2}$	38	35	$\frac{1}{16}$	3	$1\frac{7}{8}$	3
	38	35	$\frac{1}{8}$	3	$\frac{3}{4}$	$1\frac{1}{8}$
$4\frac{1}{2}$	25	30	$\frac{1}{16}$	3	4	5
	25	30	$\frac{1}{16}$	5	$2\frac{1}{2}$	$4\frac{1}{2}$
	25	30	$\frac{3}{8}$	5		$\frac{1}{2}$
	25	30	$\frac{1}{16}$	10	$1\frac{3}{4}$	$2\frac{1}{2}$
	25	30	[illegible]	10	$\frac{1}{2}$	$\frac{7}{8}$

END OR FACE MILLING OF CAST IRON.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of Cast Iron in Inches.	Under Scale of Cast Iron in Inches.
$\frac{1}{2}$	382	50	$\frac{1}{16}$	$\frac{1}{2}$	23	35
	382	50	$\frac{1}{8}$	$\frac{1}{2}$	7	11
1	191	50	$\frac{1}{16}$	1	30	40
	191	50	$\frac{1}{2}$	1	3	$5\frac{1}{2}$
$1\frac{3}{4}$	109	50	$\frac{1}{8}$	$1\frac{3}{4}$	17	23
	109	50	$\frac{3}{4}$	$1\frac{3}{4}$	$3\frac{5}{8}$	$4\frac{1}{8}$
5	42	55	$\frac{1}{4}$	5	$2\frac{5}{8}$	$4\frac{1}{8}$
16	10	45	$\frac{1}{4}$	16	$\frac{7}{8}$	1

FACE MILLING OF SOFT MACHINERY STEEL.

Diam. of Mill in Inches.	Rev. per Minute.	Speed of Cutter per Minute in Feet.	Depth of Cut in Inches.	Width of Cut in Inches.	Feed per Minute.	
					In Scale of S. M. S. in Inches.	Under Scale of S. M. S. in Inches.
$\frac{1}{2}$	267	35	$\frac{1}{16}$	$\frac{1}{2}$		
	267	35	$\frac{1}{4}$	$\frac{1}{2}$		
1	152	40	$\frac{1}{16}$	1	3	$4\frac{3}{4}$
	152	40	$\frac{1}{2}$	1		
$1\frac{3}{4}$	87	40	$\frac{1}{16}$	$1\frac{3}{4}$	$2\frac{3}{4}$	$4\frac{1}{2}$
	87	40	$\frac{3}{4}$	$1\frac{3}{4}$		$1\frac{3}{4}$

The milling machine, and in fact all the machines of the shop, can do efficient work only when they are well cared for. An important element is that they should be kept clean and well oiled.

Great care should be exercised that chips do not get into the holes in the spindles or between the arbor collars.

When at work, the milling cutter is kept flooded with oil or a solution of sal soda as already specified for lathe work.

Oil is used in milling to obtain smoother work, to make the mills last longer, and, where the nature of the work requires, to wash the chips from the work or from the teeth of the cutters. It is generally used in milling a large number of pieces of steel, wrought iron, malleable iron, or tough bronze. Frequently when only a few pieces are to be milled, it is not used, and some steel castings are milled without oil; also in cutting cast iron it is not used. For light, flat cuts it is put on with a brush, giving the work a thin covering like a varnish; for heavy cuts it should be led to the mill from the drip can that is usually sent with each machine, or it should be pumped upon or across the mill when cutting deep grooves, milling several grooves at one time, or, indeed, in milling any work where, if the chips should stick, they might catch between the teeth and sides of the grooves, and scratch or bend the work.

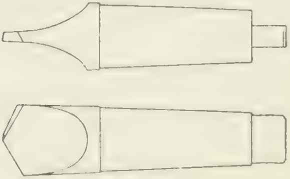


Fig. 219.

The Brown & Sharpe Co. recommend the use of lard oil in milling. Any animal or fish oil, however, may be used, and then separated from the chips by the use of a centrifugal separator, or by dumping into a tank of water. In the latter method, the chips fall to the bottom and the oil rises to the top, whence it may be drawn off with but little waste.

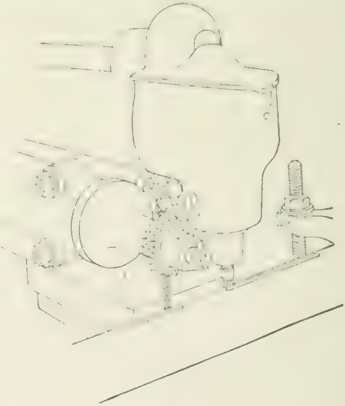


Fig. 220.

One of the operations for which the miller is particularly adapted is the laying out and drilling of holes which require to be accurately placed. The graduated feeds of the milling machine allow the distances to be set off as closely as .00025 inch, and holes can also be drilled to a given depth with equal accuracy. In starting holes, it is best to use a spotting drill, Fig. 219, which is extremely rigid and perfectly true. The spot made should be slightly greater in diameter than the drill to be used. The drill should be what is known as reamer size, that is, $\frac{1}{64}$ inch below the standard, and the hole may then be reamed, either in one operation, using a standard reamer, or by first using a machine reamer, which is about .005 inch under size, to be followed by the standard reamer. It is evident that holes thus drilled and reamed will be parallel, and, by using the vertical head, holes can be drilled at right angles in like manner. When extreme accuracy in holes is demanded, a boring bar may be used after the drill in order to correct any error due to the running of the drill itself.

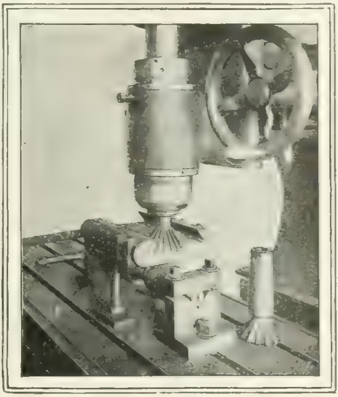


Fig. 221.

Splining Shafts. Another operation suited to the milling machine, although sometimes performed on the shaper or planer, is that of splining shafts. The slots in the table give the proper alignment to the shaft, the cutter can be set with correct relation to the axis without difficulty, and the spline cut full depth at one operation. The only objection to this form of spline is the curve at the end due to the shape of the cutter. An end mill in the vertical head can be used to remove this objectionable feature, and some splining machines are made, Fig. 220, which permanently carry both cutters, so that the work can be quickly shifted from one to the other.

The operation of making dovetails, which is a delicate and expensive job on the shaper, is readily performed on the milling

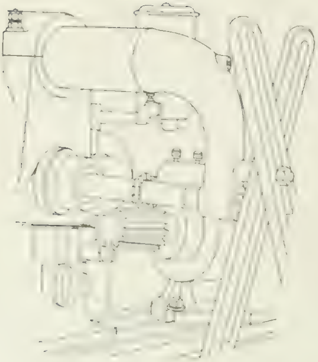


Fig. 222.

machine, especially of the vertical type, Fig. 221, the cutter being a form of end mill suited to the size and angle of the dovetail. **T**-slots are cut in a similar manner, either directly from the solid, or by following a groove made with a plain cutter.

One of the most common operations performed between centers is the fluting of taps and reamers, Fig. 222, which is done by the special cutters already referred to. It will be noticed that the cutter should be set in such a way that the cutting edge of the tap or reamer will be radial. If left as an obtuse angle, the tool will simply scrape and not cut, while if the tooth is undercut to any extent, it will be so weakened as to be liable to break.

The flutes in twist drills and in spiral fluted reamers are also cut between centers, but, if the cutter is carried directly by the spindle, the operation requires a universal machine. If the cutter be carried by a vertical or subhead of any kind, a plain machine will answer for the purpose. The angle to which the table or vertical head must be set for spiral cutting, Figs. 223 and 224, is the angle between the axis and the development of the spiral. This angle can be closely determined by the following graphical method: construct a right-angled triangle, having a base equal to the axial

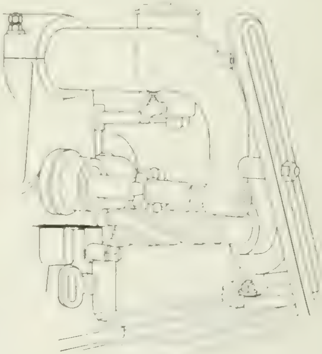
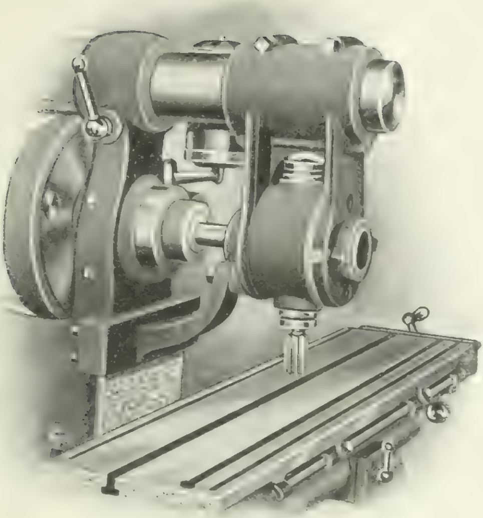
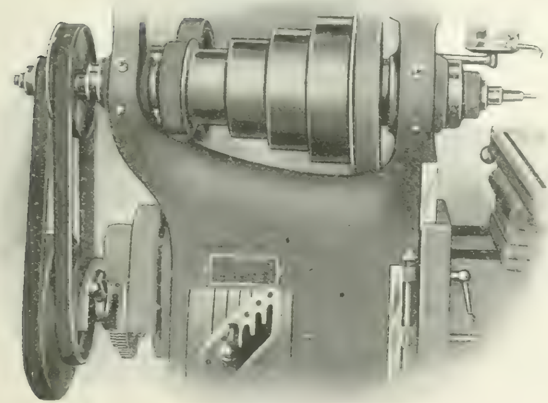


Fig. 223.



VERTICAL SPINDLE ATTACHMENT.



HIGH-SPEED ATTACHMENT.
Hendey Machine Co.

distance represented by one full turn of the spiral and a perpendicular equal to the circumference of the work. For strict accuracy, this circumference should be taken at one-half the depth of the flute. Draw the hypothenuse of this triangle, and the angle between the base and the hypothenuse may be closely determined by the use of a protractor, and will be the angle to which the table or head must be set. This angle can be more closely and quickly determined by a very simple problem in plane trigonometry, viz.:

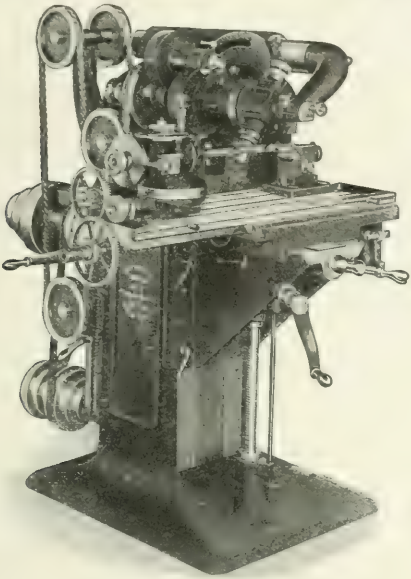


Fig. 224.

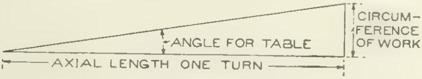


Fig. 225.

finding the sine of the angle. To do this, divide the perpendicular of this triangle by its base, and obtain the value of the angle from a table of sines.

Spirals. The cutting of spirals requires another operation different from ordinary work. In addition to the angular setting, the work must be rotated, in order to produce the spiral, as well as fed forward to the cutter. This rotation of the work must be positive, which means geared, and one rotation of the work will, of course, equal the pitch of the spiral, which is usually expressed

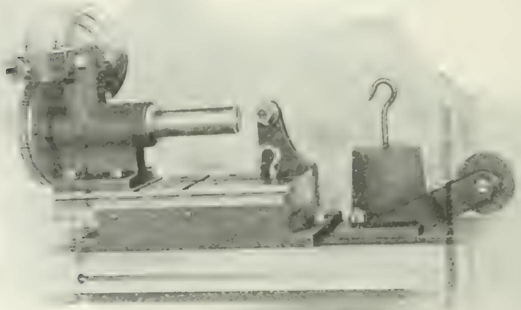
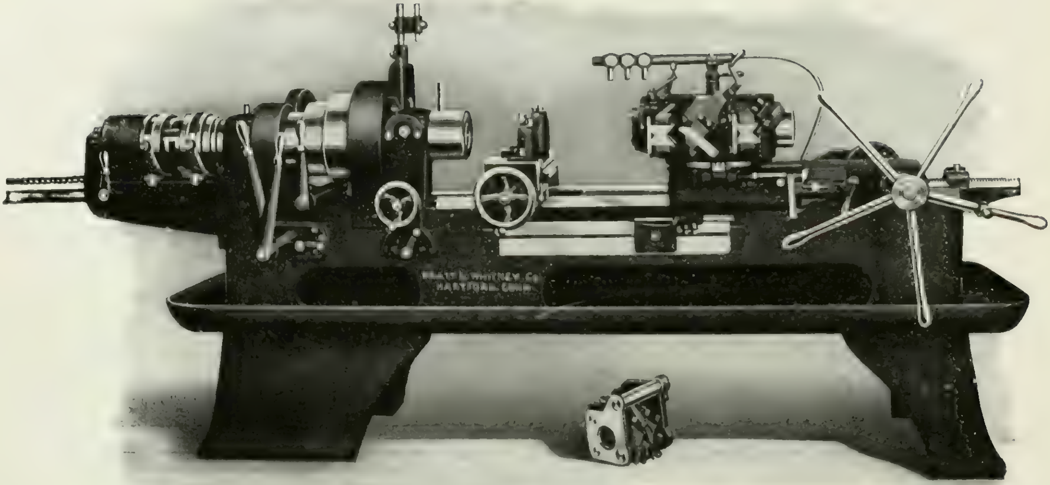


Fig. 226.

as one turn in "n" inches. After cutting one spiral groove, the work is turned and indexed the same as in plain milling.

Cams. Both open and closed cams can be readily cut on a plain milling machine by the use of the cam cutting attachment, Fig. 226, which nearly all makers are able to furnish. The outline of the cam is first laid out and worked down by hand on a plain disc, or male leader, as it is termed. This leader and a suitable blank are mounted, with their outlines coinciding, on the spindle of the cam-cutting attachment. A cam roll of the size to be used is mounted on a stationary roll stud, and an end mill of the same diameter, or enough larger for clearance, is mounted



2 x 26-INCH TURRET LATHE
Pratt and Whitney Co.

in the milling machine spindle directly opposite the cam roll. The spindle of the cam-cutting attachment is mounted on a carriage, which, by means of a weight over a pulley at the end of the milling machine table, is always kept with the leader in contact with the cam roll. A worm and worm gear are used for rotating the attachment, and thus the spindle approaches or recedes from the cam roll according to the shape of the leader. When cutting closed cams, it is sometimes desirable to use the hand-made male leader as a form from which to make a closed or female leader. This female leader will surround the cam roll in such a way that, even if the weight should fail to act, no serious damage can be done to the blank. The cutting of face cams differs from the above description only in that the spindle of the attachment is at right angles to the spindle of the milling machine instead of parallel to it. The leader and cam roll are used in the same manner as before.

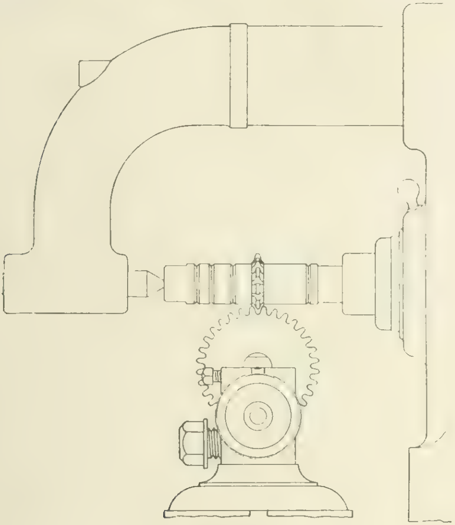


Fig. 227.

Gears. The cutting of gears of all descriptions was formerly done on some type of milling machine, although now each type of gear has its special, and, in many cases, automatic machine.

The cutters for spur and bevel gears are of two types, producing the cycloidal and involute tooth. For each pitch, the cycloidal system requires twenty four cutters, while eight cutters suffice for the involute system. These cutters are plainly marked with the style of tooth, pitch, and number of teeth for which it is suitable. Some cutters are also marked with the whole depth of the tooth expressed in thousandths of an inch. The gear blanks, having been very carefully turned as to outside diameter, are mounted on an arbor between centers, and the cutter placed so that its central plane passes through, and is parallel to, the axis of the arbor. The knee is now raised until the cutter, when rotating, just touches the outside of the blank. The work is now moved out from under the cutter, and the knee raised, using the graduated dial, an amount equal to the whole depth of the gear tooth. With the exception of the indexing, the gear is now ready to be cut, Fig. 227.

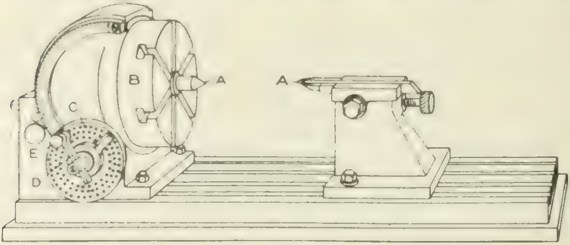


Fig. 228.

In order that the gear may be accurately and quickly set for each tooth, a dividing head is used, which is shown in Fig. 228. The mandrel upon which the gear is mounted is hung upon the centers A A, and firmly fastened to the spider B. The index plate C is geared to the spindle that carries the spider B; the index plate is drilled with a large number of holes. These holes are arranged in circles, and are accurately spaced at equal distances apart. The arm D carries a stem E, having a knurled head at one end and a pin at the other. The pin is held in one of the holes of the index plate by a spring. The arm D can be moved to any desired position, relatively to the index plate, and there fastened.

When a gear is to be cut, the arm D is moved so that the pin is opposite a row of holes the number of which is the same or a multiple of the number of teeth to be cut. Thus, suppose a gear with 45 teeth is to be made. The pin may be set opposite the circle of 90 holes. Assuming that the ratio of revolution between D and B be 40 to 1; $\frac{1}{45}$ of a revolution at B requires $\frac{40}{45}$ of a revolution at D. The pin E must, therefore, be moved $\frac{40}{45}$ of 90 holes, or 80 holes, for each tooth cut.

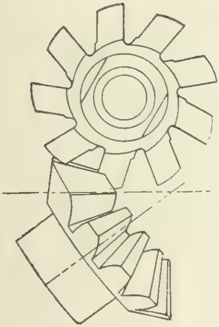


Fig. 229.

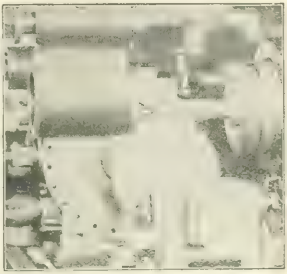


Fig. 230.

Bevel gears are held on an arbor in the dividing head, which is swung up to bring the bottom of the tooth parallel with the table, Fig. 229. As all parts of the tooth of a bevel gear are elements of a cone, it is evident that both the tooth and the space should vanish at the apex of the cone. No solid cutter, therefore, can do more than give an approximately correct shape to the tooth. Sometimes two cuts are made in order to more nearly approach perfection.

Spiral gears are cut in the same manner as any other spiral that is, by using the angular setting of the head or table together with positive rotation of the work.

Worm gears can be hobbed out by two different methods. The more common way is to gash the blank with a stocking cutter, then mount it on an arbor held loosely between centers so that the hob, when sunk into the gashes, will rotate the blank. The blank is raised slowly until the hob reaches the proper depth. A more accurate method is to positively rotate the blank at a speed corresponding to the pitch of the hob, and raise the rotating blank against the rotating hob until the proper depth is obtained. This method requires no preliminary gashing. See Fig. 230.

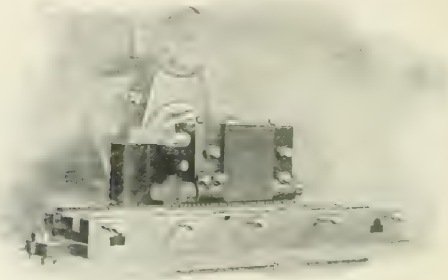


Fig. 231.

Rack cutting requires a special attachment, Fig. 231, so that the cutter spindle may be carried at right angles to the length of the table.

THE GRINDING MACHINE.

When greater accuracy than that obtainable on the milling machine or the lathe is required, recourse is had to grinding. The operation depends upon the abrasive or cutting qualities of emery, corundum and carborundum. With work properly held to a solid grinding wheel it is not difficult to attain great accuracy. By means of the grinding machine, parts may be economically finished even in hardened steel that could not possibly be machined on such shop tools as the lathe, planer, or shaper. One type of machine used for this purpose is shown in Fig. 232. With such a machine, round surfaces may be ground so that the variation from the nominal diameter is less than .0001 inch.

The grinding machine consists of a strong base A, upon which there is mounted a headstock B and a tailstock C similar in action to those of an ordinary lathe. Back of this there is an emery wheel driven by a separate belt. The principle of operation, for round surfaces, is that the part to be ground is put upon the centers, and driven exactly as in the ordinary lathe. The only additional precaution to be taken is that the driving apparatus should be secure, so that there is no looseness of the parts. This insures a continuous motion for the piece with no possibility of any black-lash. The piece turns towards the operator, and the emery wheel runs in the same direction. The two surfaces of wheel and work in contact are, therefore, moving in opposite directions.

The head- and tailstocks are mounted upon a traveling table D; this table moves back and forth in the same manner as the platen of a planer. It is made to stop automatically at each end of the stroke.

When work is being done, the piece is centered, with its axis parallel to the line of travel of the table. With the piece and emery wheel in motion, the former travels to and fro in front of the lathe. The wheel is then gradually moved forward until it has ground the work down to the size required.

It is not intended that large amounts of metal shall be removed by this machine. Its object is to reduce to accurate dimensions the work that has already been turned in the lathe. The proper method to pursue is to turn the piece to as nearly the required diameter as possible in the lathe, care being taken that it is left a trifle large. This may be .01 inch on each 2 inches of diameter. The surplus metal may then be removed by grinding. In the machine illustrated in Fig. 232, the transverse movement of the wheel-stand is adjusted by a hand-wheel graduated to read to .001 inch on the diameter of the work. The machine is also provided with an automatic cross-feed, which gives a range of advance of the wheel varying from .00025 inch to .004 inch at each reversal of the table. This feed is, furthermore, so arranged that it can be automatically released at any point.

This method of finishing is also used for pieces that have been case hardened. Case-hardening always warps the metal to

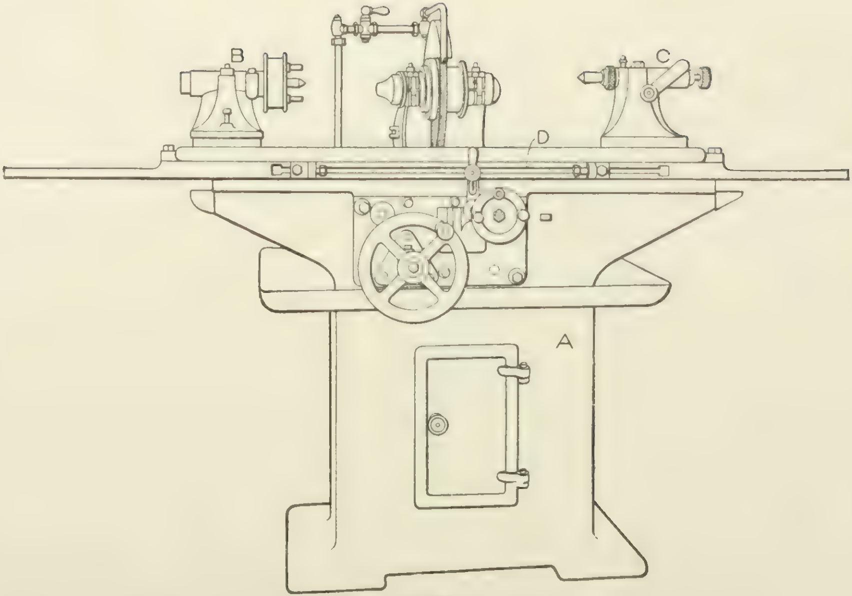


Fig. 239.

which it is applied. Grinding is resorted to in order to reduce it to the proper shape. An example of this may be taken in the method used in the manufacturing of wrought-iron locomotive crank-pins. The pin is forged and turned to as near the working size as possible. It is then case-hardened and ground to exact truth and dimensions.

Grinding is also used for truing work that comes from the lathe. The lathe does not turn its work round, owing to difference in the density of the metal, the variation of the cutting speed, the dulling of the tool, the lost motion on the centers and in the spindle, and the springing of the work itself due to the pressure of the tool.

SPEED OF GRINDING WHEELS.

Diameter of Wheel in Inches.	Maximum Revolutions per Minute.	Diameter of Wheel in Inches.	Maximum Revolutions per Minute.	Diameter of Wheel in Inches.	Maximum Revolutions per Minute.
1	19,000	5	4.400	14	1.580
1½	12.500	6	3.700	16	1.380
2	19,000	7	3.160	18	1,230
2½	8,800	8	2.770	20	1,100
3	7,400	9	2.460	22	1,000
3½	6,300	10	2,210	24	920
4	5.500	12	1,850	26	850

The grinding machine remedies this to a great extent. Partly because only a very slight pressure is brought against the work; partly because of the greater delicacy of adjustment of the grinding machine as compared with the lathe.

The method of grinding flat surfaces is practically similar to that used for round. The work is bolted to the table and moved to and fro beneath the emery wheel, which is given a transverse movement so as to cover the whole of the surface to be operated upon. The surface speed of the wheel may range from 3,000 to 5,000 feet per minute.

The above table gives the maximum speeds of caborundum wheels of various diameters.

The accuracy of grinding renders the use of fine measuring tools a necessity. The micrometer caliper, especially with the vernier graduation, is best suited for this work.

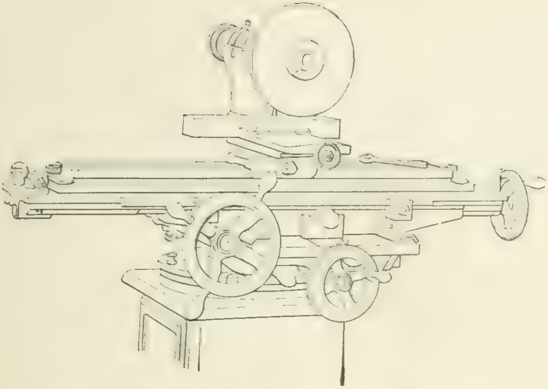
While grinding is the only method of finishing some materials, such as hardened tool steel, and the most accurate way for finishing any kind of stock, its value as an economical method is just beginning to be recognized. The general method of finishing lathe work has been to take a roughing cut with about $\frac{1}{16}$ inch feed, then a finishing cut with about $\frac{1}{100}$ inch feed, and then file to remove the tool marks. In the majority of cases it is more economical as well as more accurate to take a roughing cut with $\frac{1}{8}$ inch feed to within $\frac{1}{32}$ inch of the size, and then finish by grinding.

In some cases it is possible to get excellent results by grinding to size direct from the bar without previous turning.

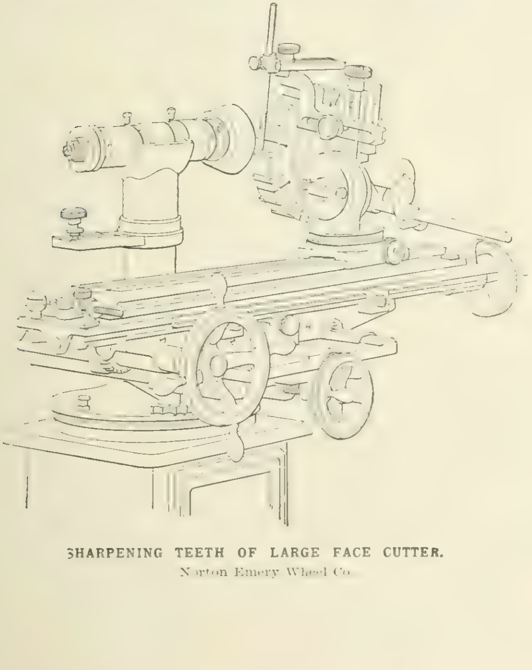
Lapping is a term applied to a particular method employed in the grinding out of holes. The lap consists of a cylinder of soft metal run rapidly inside the hole to be lapped and covered with emery and oil at the same time. The surface of the lap should invariably be of soft metal. It may be made of copper, or it may be an iron bar with a covering of lead or tin. It should be turned slightly tapering at each end, so that it will enter the hole. At the middle, it should be a tight fit.

The end of the bar is run through the hole and set on the lathe centers with a dog to drive it like an ordinary mandrel. It is covered with oil and sprinkled with emery. The lathe is then run at a high speed and the work moved to and fro over the lap. Light pieces may be held in the hand. When this is done, care should be taken to turn the piece so that the grinding may be even over the whole circumference. The tendency is, when holding work in the hand, to allow it to rest upon the top of the lap; this causes the grinding to be done on one side of the hole unless the piece is frequently turned. Laps may be used for grinding holes true and parallel. For this purpose the work should be accurately centered with the lap and firmly bolted to the lathe carriage. The lap is then run at a high speed and the work moved to and fro over it.

Laps are sometimes used for grinding flat surfaces. In such cases they are in the form of disks. They are put on the lathe



UNIVERSAL VISE ARRANGED FOR SURFACE GRINDING.



SHARPENING TEETH OF LARGE FACE CUTTER.

Norton Emery Wheel Co.

spindle in the place of the faceplate. The work is then pressed against the disk. As the outer edge of the disk has a higher speed in feet traveled per minute than those portions nearer the center, the grinding is more rapid at the edges. The work must, therefore, be constantly turned if it is held in the hand. The best way is to clamp it firmly on the lathe carriage, and press it against the lap by means of the hand feed.

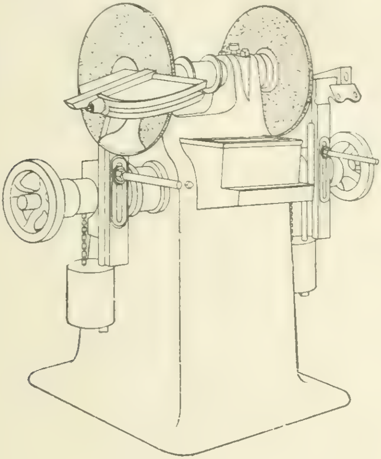


Fig. 233.

Laps for flat surfaces have grown in favor so rapidly that special machines have been made to do this work. The construction of the disk grinder can be so readily seen from the illustration (Fig. 233), that a detailed description does not seem necessary. For finishing small flat surfaces, especially those which have been hardened, this machine has become an important factor in the modern shop

LAYING OUT WORK.

Laying out work is one of the most important details of machine shop practice. Ordinarily all work is laid out. The exceptions are where certain pieces are worked from templets, and in these cases the templet is laid out from certain points on the casting, forging, punching, or whatever is used for the work in hand.

The simplest form of laying out work is to be found in the centering of round bars that are to be turned in the lathe. In this case the end of the piece is chalked. Use a pair of hermaphrodite calipers, set the points A and B so that their distance apart is a little more than the radius of the piece. Place the caliper leg at three points on the circumference, A, B, and C (Fig. 234), and describe from each the arcs of circles A′A′, B′B′, and C′C′, respectively. Then with the prick punch mark the point indicated by the small circle in the center. This will be the center. To test its accuracy, place the divider leg in the prick punch mark and see if the caliper leg will just touch the bar over its whole surface.

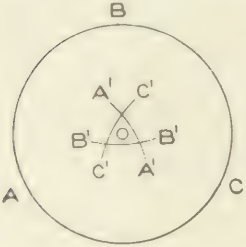


Fig. 234

Before drilling, the center should be emphasized with a center punch.

The center square may be used for this operation, as the center can be easily located at the intersection of two diameters drawn nearly at right angles. In some cases it is better to lay the shaft in V blocks on a plate and use the surface gauge, drawing at least two lines through the center of the piece.

It is usually necessary to cover the surface of the work where lines must be visible, with chalk, white lead, or copperas, before any laying out can be done; but in cases of this kind it is usual to mark directly upon the end of the bar. Before drilling, the center should be emphasized with a center punch.

The locations for holes should be at the intersection of lines in order to be plain. After marking the center with a prick punch, take a pair of dividers and scribe a circle on the prepared surface concentric with the center already located. This circle should be about the diameter of the hole to be drilled, and in many good shops it is the custom to draw another circle concentric with the first and about $\frac{1}{8}''$ larger in diameter. This outer circle is called the reference circle, and is for the benefit of the inspector when it becomes necessary to place the responsibility for a misplaced hole. These circles may be marked with at least four prick punch marks, as shown in Fig. 168, in order to indicate the position of the circle in case of the obliteration of the line. The center is then deepened by the center punch and the hole drilled. In laying out work, the first thing to do is to "snag" the work; that is, remove the ridges of the casting caused by the pattern being made in two or more parts. For small castings a coarse file is generally used, while for large work the cold chisel is used. In many shops the cold chisel is operated by compressed air.

In laying out work for the planer and milling machine great care must be exercised. It is necessary that there should be a base line to which the lines may be referred. It depends on the character of the work as to how this should be done. Sometimes it is quite sufficient to lay off the base line parallel to one side of the casting or forging. If the side thus used is to be finished, then the base line should be located at the proper distance from it to allow for the finishing. The amount required varies with the character of the casting or forging; this has been fully explained. Usually there is some outline of the rough piece that will serve as a guide.

As an example of the laying out of work, take the valve and steam chest seats shown in Figs. 235 and 236. The work is to be done on a planer. The cylinder has probably been bored. It is then placed on the planer, and so set that the center line through the cylinder is parallel to the platen of the planer. The first machine work to be done is the taking off of the roughing cut from the face A. This face is to be planed down to a certain height above the cylinder center; this height may be marked on the edge of the valve seat by the prick punch mark B. If the surface C is to be planed at the same time, its height is indicated by the prick punch mark D. These points may be located by means of the surface gauge. Set the gauge on the platen and

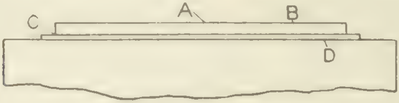


Fig. 235.

elevate the point to the proper height. Move it so that it will touch the side of the casting at the proper point, and make the marks B and D accordingly. When the surfaces A and C have

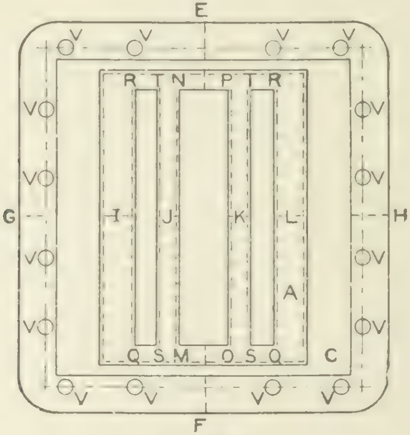


Fig. 236.

received the roughing cut, the plan may be laid off as in Fig. 236. With a square having a suitable length of blade, locate the points G and H directly over the center line of the cylinder. Cover the surfaces A and C with chalk where lines are to be drawn. Draw the lines I, J, K and L on the surface A, between G and H. Through the center of the side of the exhaust port draw the lines E and F at right angles to GH. This is done with a scriber. Lay off half the width of the exhaust port on either side of E and F, and draw the lines MN and OP parallel to E and F. In like manner, draw the lines QR and ST for the limits of the steam ports. All of these lines are to be emphasized by the use of prick punch marks as indicated.

If the sides of the valve seat are to be finished, the line to which the metal is to be cut is indicated in the same manner. Finally the holes VVV, etc., for the holding down studs of the steam chest, are to be laid out. The center lines are first drawn; then the centers of the holes are marked. After which the circles for the holes are drawn as already described.

Work is rarely laid out for the lathe. It is not necessary that it should always be done for the planer. Laying out is employed where accuracy is essential, and, where it is possible to secure the proper dimensions, with the piece to be operated upon in position on the machine.

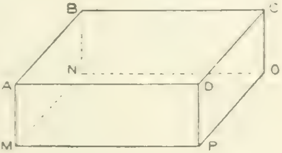


Fig. 237.

The man who has charge of the work of laying out should have some knowledge of the elementary principles of geometry. he should also have some knowledge of drawing, and should, of course, be able to read drawings.

A few general suggestions may be given regarding work to be finished in the vise on either the planer, shaper, or the milling machine, where several faces are to be finished at right angles to one another. Referring to the rectangular block of Fig. 237, the block is first placed in the vise with the face MNOP down, and the face MADP against the fixed jaw. The face ABCD is then machined, and the work turned so that ABCD is against the fixed jaw and MADP down. With the block in this position, NBCO is worked, making NBCO at right angles to ABCD. With ABCD still against the fixed jaw, and

NBCO down, surface MADP is next worked. This brings two edges at right angles to the same side and parallel to each other. Then, placing ABCD down and either MADP or NBCO against the fixed jaw, surface MNOP is generated parallel to ABCD. This leaves the ends to be finished. The vise is swung so that the fixed jaw is at right angles to the line of motion of the tool, and on the planer and shaper, they are finished by using the vertical feed. In the two last named tools, the tool holder is swung so that the tool will clear the work easily on the return stroke.

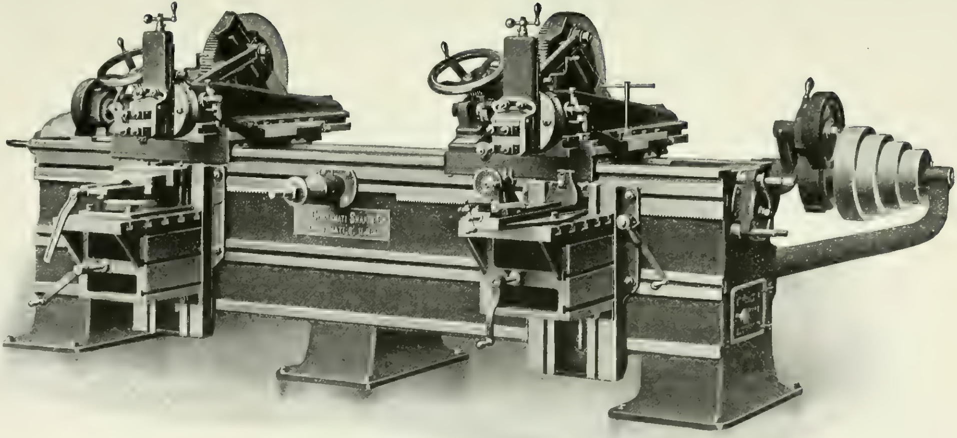
In working cast iron, it is well to chamfer the edges with a file. If this is not done, the metal will break off when the tool reaches the end of the cut, leaving a ragged edge. The depth of the chamfer depends on the amount of metal to be removed.

Fitting is the term generally applied to the hand work necessary in assembling machinery after all the machine work has been done. Filing, either in the vise or lathe, and scraping are the operations usually required, although the hammer and chisel are sometimes used. As hand work costs much more than machine work, the machining is done as closely as possible to make the hand work a very small item.

SHOP SUGGESTIONS.

In the regular work of any shop, occasions are constantly arising for the determination of the best method of doing work. The success with which the desired end is attained depends upon the skill and judgment of the man in charge. While it is impossible in a limited space to give instructions regarding every possible emergency that may arise, a few suggestions regarding shop practice will be valuable.

Pening consists in the stretching of the metal on one side of a piece of work in order to alter its shape. There is a wide difference between pening and bending. For example, suppose the curved or warped piece in Fig. 238, is to be straightened. If it were to be bent until it were straight, it would be placed on the blocks A with the concave surface down, as shown by the dotted lines. It could then be struck by the hammer and driven down past the line of support, and strained so that it would remain approximately straight. Such a method of straightening



TRAVERSE SHAPER.
The Cincinnati Shaper Company.

could not be applied to a piece of complicated outlines. It would remain wavy. In pening to truth such a piece as shown in Fig. 238 is laid on an anvil with the convex surface down. It is then struck with the pene of the hammer on the concave side. The blow must be quick and sharp. The result is that the metal is stretched at the point where the blow is struck. By working successively over the whole surface the concave side is stretched so that it is equal, in its dimensions, to the convex side. The piece then becomes straight and will so remain. A skillful use of the hammer will straighten almost any warped piece of thin metal.

Drilling Hard Metals. It is sometimes desirable to drill a hole in very hard metal. To do this the drill must be made very hard; it must be run at a very slow speed; it must be forced against the work as hard as possible without breaking the point, and it must be provided with an abundant supply of oil. For excessive hardening of a drill, it may be heated to a dull red heat, preferably in a charcoal fire, and quenched in mercury instead of water. It will also assist in the operation if the surface of the metal to be drilled is nicked with a cold chisel before work is begun. In some cases turpentine, in place of oil, may be used with beneficial results.

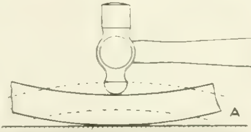


Fig. 238.

Thin chilled cast iron may be softened by placing a small piece of sulphur on the place where a hole is desired and then heating slowly to a dull red.

Glass may also be drilled. There are two methods: one is to use a flat drill moistened with camphor and turpentine, and the other is to use a copper tube with No. 60 emery or carborundum and oil. In the last method, drill half-way through, reverse, and drill to meet, removing the fin at the center with a round file wet with water or turpentine.

Grinding Valves. This is a kind of grinding that is usually done by hand. It consists of fitting a valve and its seat so that they are in metallic contact. In its results it is the same as scraping. The process is very simple. The valve is coated with oil and some fine emery sprinkled over it. It is then put on the seat and worked back and forth or revolved. The emery serves to grind off the high surfaces of each. After grinding for a time, remove the valve and wipe both surfaces clean. The metal on each will show where they have been in contact. When these indications appear over the whole of the surface, or in a continuous ring about the seat of a circular valve, the work is completed.

To generate a surface plate it is necessary to work with three at the same time. For the sake of making the explanation clear they will be called A, B, and C. After the plates have been planed, a straight edge should be laid on each. A straight edge is merely a piece of flat steel having one or both edges true and straight. Set the straight edge on the plates in all directions. If it touches over its whole length in all positions, then the plates are ready for scraping. If it touches at the edges of the plate and is clear in the center, the former are high and should be filed down. If it touches in the center and rocks to and fro, the plate is convex and the center must be filed down. After the plates have been filed to truth as far as truth can be indicated by the straight edge, they are ready for scraping.

Now take plates A and B and place them face to face. Strike a blow on the upper one, and it will cause a jarring sound to be heard. This shows that the two are not in perfect contact. Smear the surface of plate A with a thin mixture of red lead and oil. Cover the surface evenly and thinly. Then rub the two plates together, and where the red lead rubs off on to the surface of plate B the two come in contact. Take the scraper and scrape off a little of the metal from each of the plates where they have been in contact. Wipe off plate B, and again smearing plate A, proceed as before. Continue this process until the two surfaces are in contact over their whole areas. This does not prove, however, that they are flat. They may be in contact, as required, if A is convex and B is concave. To test this the third plate is necessary. Smear plate B with red lead and scrape C to fit it. Do not touch A. It is evident that A and C will then be alike. Bring them together. If they are both convex they will roll over each other. If they are concave they will bear at their edges and not touch in the center. They will appear to be out of truth by twice the actual amount. Scrape off the contact points of A and C. Remove as nearly as possible the same amount of metal from each. When these two plates have been brought so as to be in contact over their whole areas, lay plate A aside and scrape B until it fits C, but do not touch A. Then try A and B together. If they do not touch over their whole areas, treat them as before described for A and C. Then introduce C again. Continue this alternating process until the three plates form a bearing over the whole of the surface of each of the other two.

During the latter part of the process, use alcohol instead of red lead. This will leave clean, bright spots at the points of contact.

Fitting Brasses is a piece of work that is now usually done on a machine, but which is sometimes done by hand. Brasses that are to be used for connecting rods, and which are made in two pieces as shown in Fig. 239, have a tendency to warp after the machine work has been done upon them. The difficulty arises from their closing along the diameter A. Thus if the brass is finished, and the hole bored out to the proper diameter, and is then cut apart on the line CD, it will be found, shortly afterwards, that the diameter A is less than the diameter B. It may, therefore, be necessary to bore the hole somewhat larger than the working diameter. The kerf made by the saw will usually allow the parts to be drawn together along the diameter B so that it will more than make up for the shrinkage at A. The hole can then be scraped to fit the pin. The brasses should always be keyed solidly metal to metal. This avoids a wear of the sides and edges of the metal due to the thrust of the rod.

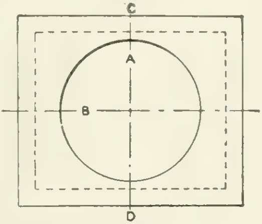


Fig. 239.

Joints. Where a gas or liquid is to be retained in a pipe or other vessel without leakage, a tight joint is necessary. The method of grinding valves to their seats has already been explained. In that case it was shown that a metallic contact between the valve and its seat is all that is required in order to make it a tight joint. Two surfaces that have been scraped to fit will also accomplish the same purpose. This is frequently too expensive an operation to be performed, especially on rough work. In such places a soft material may be interposed between the two surfaces. Where the joint is to be a permanent one and is not to be taken down, the red lead joint is usually employed. This consists in the use of a mixture of red and white lead between the joints. To ordinary white lead ground in oil add enough dry red lead to make a paste that can be spread without sticking to the blade with which it is applied. After the mixture has been made, it will be improved by pounding it well with the hammer. It may then be laid between the two pieces of metal forming the sides of the joint and the latter be drawn together. Red lead joints are extensively used in pipe fitting. The red lead has a tendency to rust the iron with which it is in contact, and thus form a very tight connection between the two pieces. Where provision is to be made for taking down the joint at a future time, it is better to use a graphite paste made for the purpose. This does not rust the metal; it forms a perfectly tight joint and one which may be taken down without difficulty at any time.

Joints that are subject to occasional disconnecting can be best held by a disk of rubber packing. The latter is cut to fit the flanges between which the joint is to be made, and they are then drawn tightly together.

Joints that are to be frequently taken down are usually packed with a piece of copper wire. Such a place is the joint between the steam chest and cylinder of a locomotive engine. A groove is cut in the two surfaces and a copper wire is laid therein. This wire should be about $\frac{1}{4}$ inch in diameter. Its size, however, depends upon the joint to be packed. The ends of the wire are soldered together so that no leakage may occur past the ends.

Another form of joint is the rust joint. This is always permanent in character. The making of such a joint consists in rusting the two surfaces together. The following are the proportions by weight of the rusting material: 100 parts of iron turnings; 1 part of sal ammoniac, and ½ part of sulphur. The setting of the joint can be hastened by increasing the amount of sal ammoniac from 15 to 25 per cent. Mix the ingredients thoroughly and just cover them with water.

Fluting Rollers. Where feed rollers such as those used in wood-working machinery are to be turned and fluted, the turning should always be done first. This insures a continuous surface for the cutting tool. Where old rollers are to be re-turned and fluted, the same rule applies. The fluted surface may be turned to size. The lathe tool will break the edge of the ribs away but when the fluting is done, these edges are again made smooth The fluting can be done on a planer with a round-nosed tool. The roller should be held on centers and clamped so that each groove may be presented to the tool in succession. A planer center, as illustrated in Fig. 178, affords a convenient method of holding and turning the work.

Scale. Whenever a piece of cast iron is to be turned, the point of the tool should always be made to work beneath the scale. The scale is the hard outer shell that covers all cast iron as it comes from the foundry. It is very hard and brittle. If the edge of the tool is made to work in or against it, that edge will soon be dulled. If it is beneath it, the raising of the chip cracks and removes the scale.

Pickling. Where castings are to be worked, either in the lathe or planer, to dimensions only a little less than that when rough, they should be pickled. This consists in washing them with a solution of sulphuric acid and water. The castings may be either submerged in or swabbed with the solution. The effect of pickling is to cause the scale to drop off in flakes, leaving the metal bare, unprotected and rusty. The casting should then be washed with a sal soda solution. A good solution for this work is to use 1 part of commercial sulphuric acid in 10 parts of water.

Cold Chisels. It is well to use a coarser grade of steel for cold chisels than for lathe or planer tools. A coarse-grained metal is preferable because the continual hammering in use and redressing will gradually modify the granular structure until it is microscopic in its fineness. In dressing, it should never be heated above a cherry red, and the temper should be drawn well down so that the soft metal backs up the edge. A capacity to receive a multitude of grindings is not what is wanted. The tool must be able to endure the severe service for which it is intended. It must cut into a distorted mass of metal, where every blow gives it a shock tending to form a new arrangement of its particles. It never receives the steady pressure of the lathe tool, hence its powers of endurance must be greater.

Lining Shafting. In equipping a shop, the first work of the machinist is the erection of the shafting. The main line should be the first laid out, and the engine, together with the jack and countershafting, must be located from it. After placing the hangers as nearly as possible in a horizontal line, the shafting should be placed in the boxes and attached to the hangers. For lining the shaft, a level and a fine grass or silk line are indispensable. The line is tightly drawn, horizontally, a short distance from the position it is desired that the shaft shall occupy, and the distance from the surface of the shaft to the line is measured and made equal near each hanger by a stick such as is shown in Fig. 240.

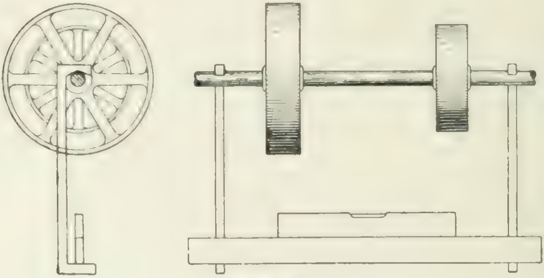


Fig. 240.

The level is used to make the shaft horizontal, and, if the hangers are adjustable in two planes, the operation is quite rapid.

When other shafting is to be erected parallel to the first, if the distance does not exceed twelve or fifteen feet, a long stick such as shown in Fig. 241 may be used by driving a nail into the end of the stick to allow some adjustment. The level is used as before.

When the distance is great, or obstacles prevent the use of the stick as suggested, a line may be drawn on the floor of the shop by dropping a plumb line from near the ends of the first shaft and connecting the points located. Another line, directly under the desired location, may be drawn by direct measurement, and the second shaft erected by dropping a plumb line to this second floor line near the ends of the second shaft. This method may be employed, with such variations as the case may demand, even though a floor or wall be between the locations.

In leveling up long lines, or around machines, or through walls, the hydrostatic level is a most convenient tool. It consists of two graduated glass tubes set in suitable bases and connected by a rubber tube. When the rubber tube is filled with water, and the glass tubes placed vertically on the shaft, the fluid should stand at the same gradation in each glass. These levels are made with self-acting valves to prevent the escape of the fluid.

When pulleys or hangers make the direct application of a level to the shaft impracticable, leveling hooks, in connection with a wooden straight-edge, as shown in Fig. 240 are very convenient. These may be made of wood or metal, and of lengths suitable to the case in hand.

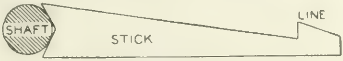


Fig. 241.

Machine Setting. After the shafting is erected, comes the setting of machines. The countershafts are first erected parallel to the main line, and with due regard to the location of the machine. The machine is then placed with its driving shaft parallel to the counter by use of the plumb line, and the platen, table, or other horizontal surface carefully leveled, in two planes by wedging up the machine with common shingles. It is then secured to the floor by lag screws.

When the machines are very heavy, and stone or masonry foundations necessary, anchor bolts are built into the foundation at suitable points or holes drilled for expansion bolts. The machine is then lined and leveled as already suggested, but the bottom of the machine is usually a rough casting, the top of the stone foundation is still rougher, and as the wedges are likely to slip out under the jarring of the machine, a permanent support must be provided. This may be done by pouring melted sulphur beneath the bed. To do this, build a dam of clay or sand all around the bed and about 2 inches high. Melt ordinary stick sulphur or brimstone in ladles, and pour in at several points at once. Keep the space flooded until the dam is well filled, and allow it to harden. This will occur very quickly, after which the dam may be removed and the sulphur cut away from the edge of the machine. Care must be taken that the temperature of the sulphur is as high as possible before pouring. Unless this is done it will cool and set before reaching the inmost recesses beneath the machine. It will then crumble because of insufficient bearing surface to carry the imposed weight. The nuts are then screwed down on the bolts and the machine is secure.

Belting. The shafting and machines are usually driven by belting, and a few remarks on this subject may be desirable. Leather is the material generally employed, and the belting may be from single to six-ply in any suitable width. Single belting has a flesh and a grain or hair side, and should be run with the grain side in contact with the pulley. The ends are cut square, and fastened by hooks, coiled wire, or rawhide lacing.

Leather belting is injured by water, steam, oil, and temperature above 110° F. Where such conditions exist, cotton belts, faced with thin leather, or rubber belts may be used. These belts are cheaper than leather, are about as strong, and will transmit power as effectually; but they will not stand mutilation of the edges. This is a point of prime importance, and prohibits their use in many cases.

The power transmitted by a belt is directly proportional to its speed and width. A safe rule is to allow one horse-power for a speed of 1,000 feet per minute, with a single-thick belt one inch wide. This is a more liberal allowance in favor of the belt than is usually given, but will increase the life of the belt in far greater proportion than the increase in first cost. Double belts will transmit about one and one-half times as much power as single belts. The above rule applies to belts running over pulleys of equal diameter, or, in other words, to cases where the arc of contact is 180°. For smaller arcs of contact use the coefficients found in the following table:

90°	100°	110°	120°	130°	140°	150°	160°	170°	180°	200°
.65	.70	.75	.79	.83	.87	.91	.94	.97	1.	1.05

To increase the power transmitted, either increase the speed of the belt by using larger pulleys, or use a wider belt.

A 3-inch single belt is running over a 24-inch driving pulley which makes 200 R.P.M. (revolutions per minute). How many H.P. will it transmit?

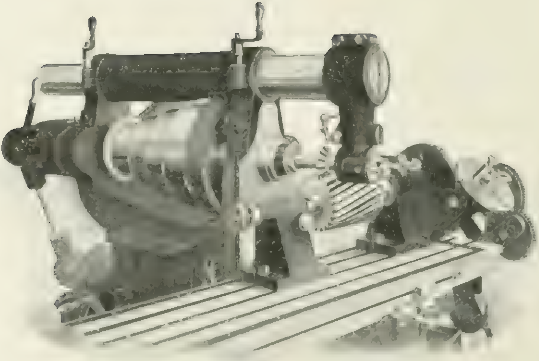
The circumference of the pulley in feet is 2 × 3.1416 = 6.2832 feet. As the speed of the pulley is 200 R.P.M., the speed of the belt will be 200 × 6.2832 = 1256.64 feet per minute. For every inch of width it will transmit 1256.64 ÷ 1000 = 1.25664 H.P. Then a 3-inch belt will transmit 3 × 1.25664 = 3.76992 H.P. *Ans.* 3.75 H.P. (approx.).

It is desired to increase the H.P. in the above example to 5 H.P. How may it be done?

(1). By using a wider belt in the proportion of 3.75 to 5. 3.75 : 5 : : 3 : 4. *Ans.* By using a 4-inch belt.

(2). By using a larger pulley in the same proportion. 3.75 : 5 : : 24 : 32. *Ans.* By using a 32-inch pulley.

(3). By using a double belt. 1 : 1.5 : : 3.75 : 5.63. This would give a little better result than required.



CUTTER 8 IN. DIAMETER. SPEED 40 FEET PER MINUTE.

CUTTER ¾-IN. DIAMETER. SPEED 83 FEET PER MINUTE.

Examples of Plain Milling.

Cincinnati Milling Machine Co.

THE VERTICAL MILLING MACHINE

Among the many new machines that have been built and put on the market within the last decade and a half, we doubt if any has become more indispensable to the manufacturer of machinery of every description than the Vertical Milling Machine. Its advantages over even the latest designs of the horizontal type are now universally recognized for many classes of manufactured work. For finishing surfaces—usually done on the planer or shaper or in the lathe—the vertical milling machine fills a place in general manufacturing plants with absolute success. For circular or straight work, for finishing surfaces both horizontal and vertical that are either difficult or impossible to get at with lathe or planer, the vertical machine has no equal. It is impossible to exaggerate its utility as an economizer of labor and as a producer of work impossible to perform with other tools.

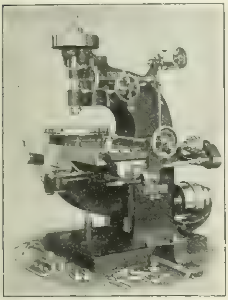


Fig. 1. Modern Vertical Milling Machine.

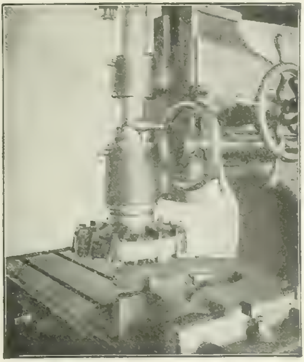


Fig. 2. Facing a Plane Surface with Inserted-Tooth Tool.

In Fig. 2 is shown a twelve-inch inserted-tooth face mill, roughing off a plane surface, and this also shows the correct practice in using cutters of this kind on a vertical machine. The cutter is fitted to the nose of the spindle which secures great rigidity. Its economy over a planer in this class of work is from three (and even more) to one; and if the parts have to be scraped to a fit or a finish, the labor is reduced in like proportion.

On the other hand, if it is necessary to cut into the recess in the center of the casting, a cutter similar to that shown in Fig. 3 could be used. This style of tool on a vertical milling machine is what might be called a "universal cutter," or "end-and-side" mill; and Fig. 3 shows how it is used on what would be an awkward job to do on the planer. It matters not whether the end of the table to be milled is one or six inches thick; at the lowest estimate the planer is the loser, three to one. If, for instance, the piece is comparatively short, and requires finishing on both ends, no change of tools is necessary, the table being simply moved along until the other end of the piece is in position to be milled to its proper dimensions.

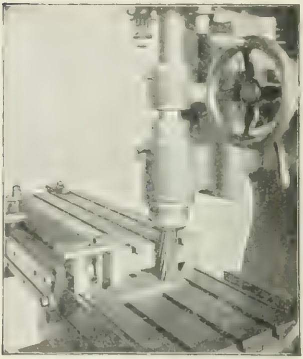


Fig. 3. Universal Cutter for End-and-Side Milling.

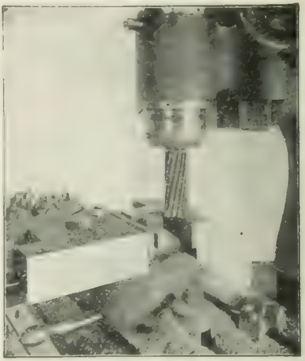


Fig. 4. Small Parts Rapidly Finished in Vertical Milling Machine.

The advantage on small pieces, as shown in Fig. 4, is manifest; and the same style of cutter, if used as a combined end-and-side mill, will do more in one hour than could be accomplished by a shaper in six hours. This class of work as a rule uses up much time on machines that could be employed to better economy on other and larger work; while the fact that the same tool can be used for working on either side or the surface without change, recommends vertical milling to the up-to-date manufacturer.

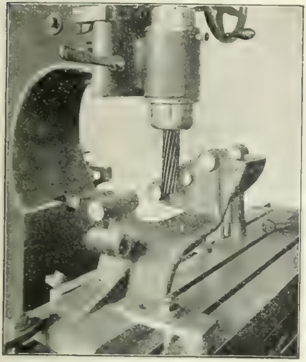


Fig. 5. Facing Spots at Irregular Intervals and at Right Angles.

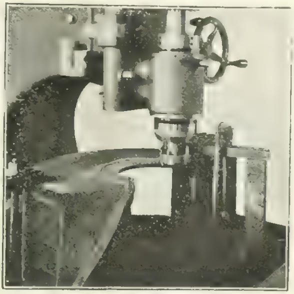


Fig. 6. Finishing Inside Edge of Casting

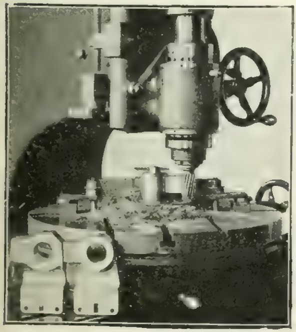


Fig. 7. Finishing Horizontal Plane and Vertical Curve at one Operation.

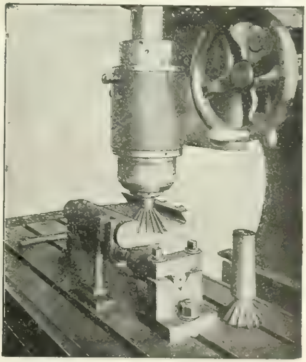


Fig. 8. An Example of Angular Milling

Milling or planing spots that come at irregular intervals or at right angles with each other, has never been a practical operation in the general run of work found in machine shops. The work is usually done by hand, or, when required to be of a better finish, is counter bored. Take for instance a bracket, as shown in Fig. 5, with spots to be finished on both ends, on the inside, at different levels and at right angles with each other—a difficult subject to handle by any method other than the use of a vertical milling machine. This class of work can be done at an economy of four to one over any other method, with a saving of time on all subsequent operations; and it also insures all surfaces being parallel or square with each other, without changing the setting of the work.

On the piece shown in Fig. 6, the same style of cutter could be used for finishing spots on the inside surface of a casting, or for finishing the top edge of the casting, or the top and sides of the plate, by which it is fastened to the machine. In the hands of a skillful workman, even the outside irregular surface could be easily finished with an economy over any other method, of ten to one.

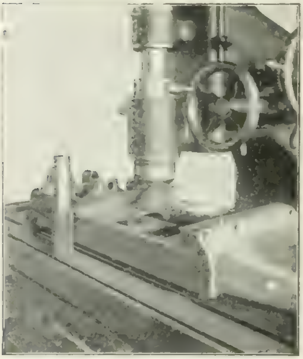


Fig. 9. Vertical and Horizontal Angular Milling with Two Tools

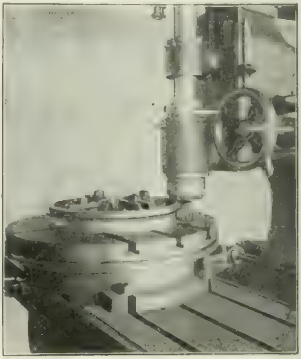


Fig. 10. Circular Bevel Milling.

The universal use of the end-and-side mill in the vertical milling machine is strikingly shown in Fig. 7, where one is used in finishing a horizontal plane surface and the vertical segment of an arc, at one operation and in one-tenth of the time required in a lathe. An end-and-side mill should as a rule be made with special flutes; and, if over one and one-half inches in diameter, it would be of advantage to have the teeth nicked to break up the chips.

Two examples of angular milling are shown in Figs. 8 and 9;

and in each case it may be noticed that there are vertical surfaces to be milled, and also horizontal edges to be finished. These are taken care of, first by the use of the end-and-side mill shown standing on the table in Fig. 9; and then the angular or dovetail mill is substituted, and the undercut is made. One can readily see that there is no end to the work of this kind that can be done—slotting in places absolutely inaccessible to ordinary methods; undercutting and bevel or dovetail work in straight line or circle; and inside profile work, either freehand or by the use of profile pattern gauges. Some of this work can be done by no other method on a machine, and, until the advent of the vertical milling machine, was done by hand. The saving in time on such work will cover the expense of the machine in a comparatively short time, let alone the accuracy and amount of the work performed.

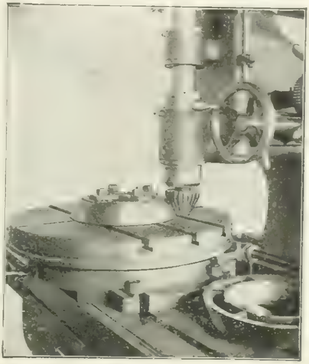


Fig 11. Ball Cutter Used with Rotary Table.

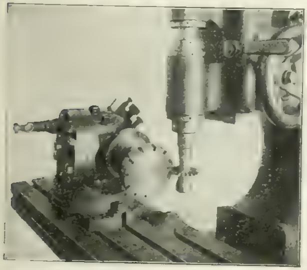
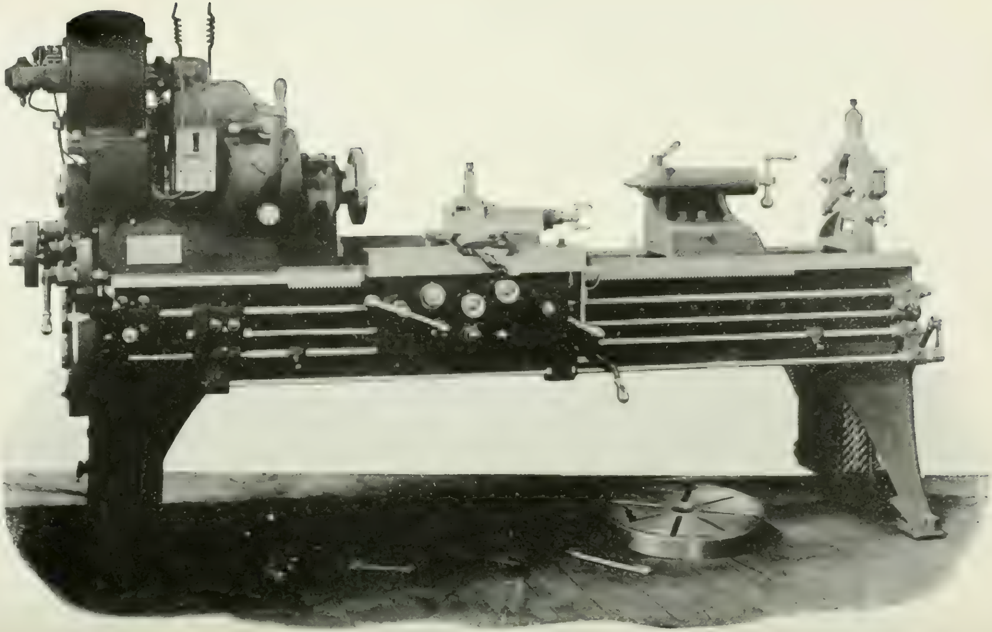


Fig. 12 Method of Cutting Slots Around Edge of Blank.

Fig 10 shows an example of outside and inside bevel circular milling; and the piece lying on the platen shows also a circular recess done by the end-and-side mill. In fact, all the finish on this piece—top, bottom, inside, and outside—has been done by the use of the bevel and the end-and-side-mill, on a power-driven rotary table, at a saving over the method of turning on a lathe, of four-fifths of the cost.

The T-slots in the rotary table are done with a T-slot cutter. The ball cutter used in connection with the rotary table is shown in Fig. 11; and it can be readily seen how the handle, which is connected with the vertical feed of the head, is finished by the use of a concave mill. By using a universal dividing head, all the usual work done on the horizontal milling machine can be done. Fig. 12 shows the method of cutting the slots in the blank for an inserted-tooth cutter to be used on the vertical milling machine.

The use of the vertical milling machine seems to be growing more and more in favor with manufacturers of machinery and hardware sundries. The writer has in mind a case where a large door frame for a boiler front was to be faced off, and the door milled to fit. The old method was to chip and file until the fit was made, which required nearly three hours' labor for one man. By the use of the vertical milling machine the time was reduced to about twenty minutes. This is only one of many thousands of cases where the supremacy of this machine is so apparent that the manufacturers have been obliged either to introduce it as a money saver in their factories or to continue to be classed as behind the times.



LATHE WITH SINGLE-VOLTAGE FIELD-WEAKENING MOTOR.

Controller Operated by a Handle on the Carriage.

ELECTRIC MOTORS IN MACHINE-SHOP SERVICE.*

I intend to consider the subject "electric motors in machine-shop service" from the standpoint of the shop engineer, whose one thought is economy in the broadest sense of the word. To such a man, the motor is but a single detail of the equipment - possibly one of the most important details, but only so when its relation to the problem as a whole, is understood. The development of alloy steels, permitting of cutting speeds from two to four times as great as was heretofore possible, requiring, in many instances, machines of new design; the introduction of the grinding machine, which is rapidly replacing the lathe for much finishing work; the milling machine; the electric motor as a means of driving; and types of management to assure efficient use of equipment, are among the most important factors requiring his attention.

The manufacturers of electrical apparatus too often defeat their own ends by overenthusiasm, or rather, by extravagant claims that they cannot possibly substantiate. There is no use trying to convince the shop engineer that the words "motive drive" are synonymous with "low cost," for he knows that efficiency attained depends upon the co-operation of a multitude of things, and primarily the intelligence with which the equipment is handled. If, however, the possibilities of the motor drive are properly presented, he can appreciate them better than any one else, for they fill a definite need, the importance of which he will understand.

It is not necessary to dwell upon substantial progress recently made in shop practice, which has resulted, in many instances, in greatly increased output with consequent reduction in cost. I shall consider rather what is needed to increase efficiency in the average shop, where it is still extremely low, for even when adequate funds are provided for the purchase of new equipment, the end in view is often defeated through lack of proper insight in connection with its purchases, installation, and use.

At the same time electrical manufacturers have not made the progress that would have been the case had they possessed a thorough understanding of shop requirements. Our experience has been confined largely to the installation and operation of electrical equipment under working conditions, therefore I shall treat the subject from this side, with the hope that I may bring more

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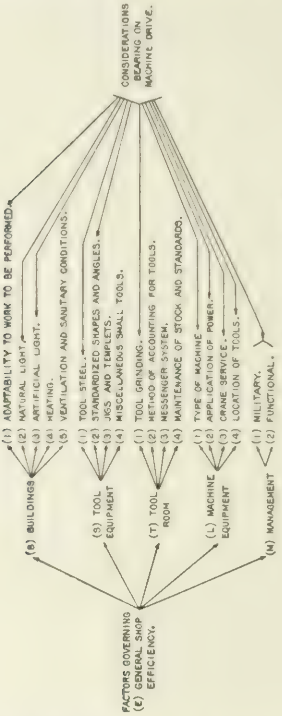
*This paper was presented before the International Electrical Congress of St. Louis, 1904, by Charles Day of the firm of Dodge & Day, Engineers, Philadelphia, Pa.; and is reprinted by special permission.

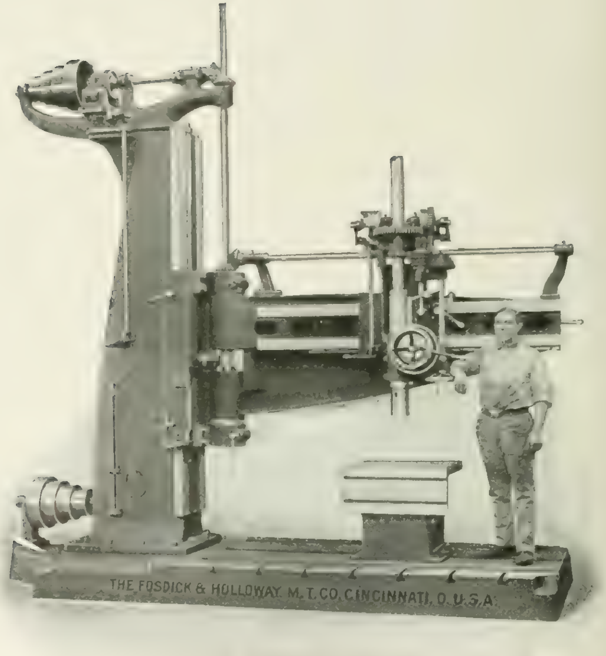

CONSIDERATIONS BEARING ON MACHINE DRIVE.
(1) ADAPTABILITY TO WORK TO BE PERFORMED.
(2) NATURAL LIGHT.
(3) ARTIFICIAL LIGHT.
(4) HEATING.
(5) VENTILATION AND SANITARY CONDITIONS.
(1) TOOL STEEL.
(2) STANDARDIZED SHAPES AND ANGLES.
(3) JIGS AND TEMPLETS.
(4) MISCELLANEOUS SMALL TOOLS.
(1) TOOL GRINDING.
(2) METHOD OF ACCOUNTING FOR TOOLS.
(3) MESSENGER SYSTEM.
(4) MAINTENANCE OF STOCK AND STANDARDS.
(1) TYPE OF MACHINE
(2) APPLICATION OF POWER.
(3) CRANE SERVICE.
(4) LOCATION OF TOOLS.
(1) MILITARY.
(2) FUNCTIONAL.
(B) BUILDINGS
(S) TOOL EQUIPMENT
(T) TOOL ROOM
(L) MACHINE EQUIPMENT
(M) MANAGEMENT
FACTORS GOVERNING (E) GENERAL SHOP EFFICIENCY.

Shop Considerations Bearing on Machine Drive

Fig. 1

clearly before the manufacturers the conditions they must meet. and at the same time aid the customer in specifying his requirements and securing results.

Generally speaking, the electric motor (either for group driving or individual operation of machines) is conceded as the proper



EIGHT-FOOT ARM RADIAL DRILL.
Fosdick Mach. Tool Co.

means of power distribution. My paper will deal with the subject under the following headings:

(1) Shop Requirements.
(2) Notes Concerning Motor-Drive Systems.
(3) Notes Concerning Different Makes of Apparatus.
(4) General Conclusions.

(1) SHOP REQUIREMENTS.[1]

My paper will only permit of a general outline of shop considerations bearing on the subject; these are illustrated in Fig. 1. Each factor must be carefully considered and, when treating the subject generally, certain assumptions made. For example, we are justified in assuming that the best tool steel should be used and design accordingly, while crane service and type of workmen are, on the other hand, matters depending on class of work handled and local conditions.

An intimate knowledge of shop practice is quite as necessary to the designer of electrical apparatus for machine *driving* as to the builder of the machine, and, while frequently difficult to show the direct bearing of the various features of management and methods upon a single factor, such as the one under consideration, the most useful conclusions can be drawn only by those familiar with the subject in detail. Improved systems of management are doing much to assure proper use of equipment, but in any event the need of explanation in connection with its operation should be eliminated to as great a degree as is possible. In other words, apparatus should primarily be designed to give satisfactory results in the hands of average workers. Where its adjustment and manipulation is dependent upon the operator, he must be fully considered in the design, but when attention is required for inspection at intervals only, the personal equation does not enter into the problem to as great an extent. Lathe and elevator drives illustrate the two cases.

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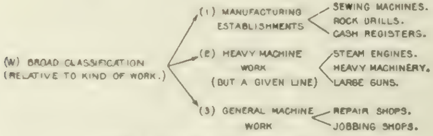
[1] The words "machine" and "tool," as used in connection with machine-shop work, are very frequently ambiguous. I will use them in the following sense: *Machine.*—Definition (Standard Dictionary). Any combination of inanimate mechanism for *utilizing* or *applying power*. A construction for mechanical production or modification. Example - Lathes, pneumatic drills, power shears, etc. *Machine Tool.*—This term is often confusing and need not be used in present paper. *Tool.* Definition (Standard Dictionary). A *hand instrument*. Not a mechanism. Used directly for production. Examples.—Chisel, hammer, saw, etc.

Tools for removing metals will be further subdivided as follows: Cutters, millers, drills, etc.

If cuts are of long duration, the cutting speed can readily be determined by experiment, but this is not practical in the run of machine shop work. The determination of cutting speed for miscellaneous work is a difficult matter, and must be given special study in each case, every means toward uniformity of product being resorted to.

The drive is but a detail of the machine. We should aim at a harmonious whole, not combining an efficient drive with an out-of date tool. The motor driven tool of the future should not be considered a combination, but a *unit* suited to certain specific ends The motor drive problem is essentially a matter for the machine builder to settle, and when a machine is purchased, the customer should have the assurance *that the drive has been given the same care in design and construction as any other part of the machine, and need not be considered as a distinct issue.*



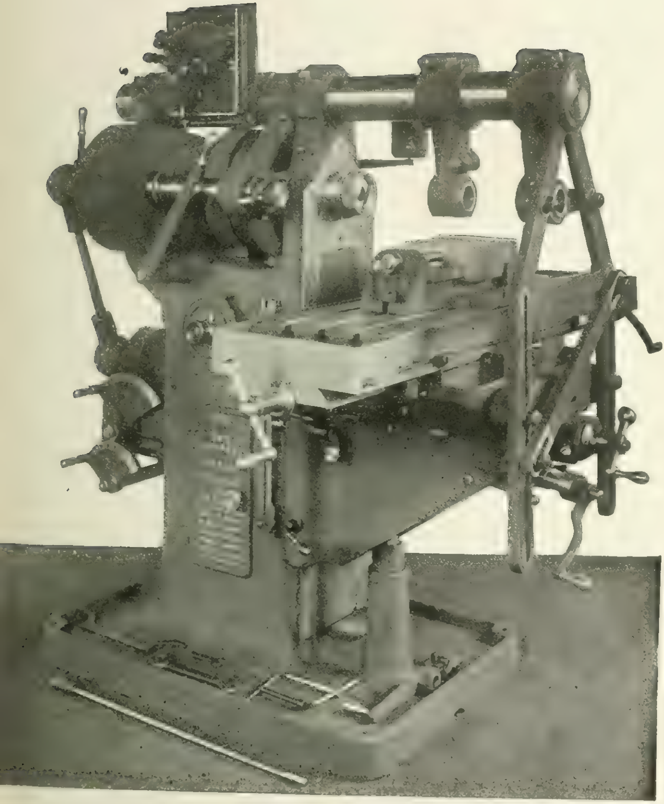
General Machine Shop Classification

Fig. 2.

Machine shops may be broadly classified according to character of output as follows:

Shops of the first class can be laid out in every detail with regard to a definite need. Machines are purchased to do just one job, and frequently it pays to design special machinery for such duty. After it is properly adjusted for the character of material to be worked and for the cutters, no changes are required until better methods or facilities are developed. Here, as far as the drive is concerned, we find the simplest conditions. Usually constant speed with adequate power suits the case.

In shops classified under the second heading, little opportunity for duplication, in the sense just considered, exists. Machines

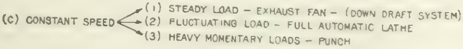


ELECTRICALLY-DRIVEN PLAIN MILLING MACHINE

Showing Field Rheostat.

The Cincinnati Milling Machine Co.

must handle a variety of work, and even those purchased for specific operations are usually suited for other purposes so they may be kept busy the greater part of the time. Variation in size of work, material and cutters, demands an adjustable speed drive

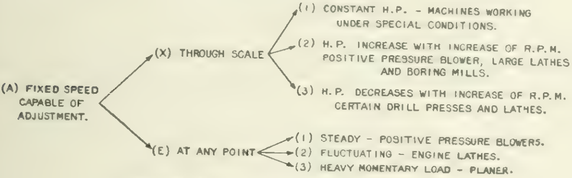

(C) CONSTANT SPEED
(1) STEADY LOAD – EXHAUST FAN – (DOWN DRAFT SYSTEM)
(2) FLUCTUATING LOAD – FULL AUTOMATIC LATHE
(3) HEAVY MOMENTARY LOADS – PUNCH

Character of Load for Constant Speed Drive.

Fig. 3.

together with change feeds, if most economical results are desired. This is true to a still greater degree for machines in the third class.

The drive requirements from a consideration of work to be performed can be further analyzed as shown below:


(A) FIXED SPEED CAPABLE OF ADJUSTMENT.
(X) THROUGH SCALE
(1) CONSTANT H.P. – MACHINES WORKING UNDER SPECIAL CONDITIONS.
(2) H.P. INCREASE WITH INCREASE OF R.P.M. POSITIVE PRESSURE BLOWER, LARGE LATHES AND BORING MILLS.
(3) H.P. DECREASES WITH INCREASE OF R.P.M. CERTAIN DRILL PRESSES AND LATHES.
(E) AT ANY POINT
(1) STEADY – POSITIVE PRESSURE BLOWERS.
(2) FLUCTUATING – ENGINE LATHES.
(3) HEAVY MOMENTARY LOAD – PLANER.

Character of Load for Adjustable Speed Drive.

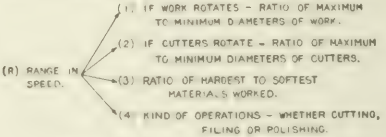
Fig. 4.

Figs. 3 and 4 relate to *character* of load. Figs. 5 and 6 are a further analysis of adjustable speed drive, for machines using cutters, giving details that should determine *range* and *number* of speeds.

Adjustable speed[2] may be desirable on grinding machines also, and in this case will depend on ratio of maximum to minimum wheel diameters and other matters that must be considered separately in individual cases.

[2] The words "variable speed" are now generally used for describing motors adapted for individual operation of machines, but to distinguish from the crane motor, for example, which is truly the variable-speed type, I shall use the words "adjustable speed" as describing a fixed speed capable of adjustment over a given range. Variable-speed motors are used principally for railway and crane service where the load is intermittent and torque variable. Direct-current apparatus has been developed to give such thoroughly satisfactory results for this duty that I shall not consider it other than in its relation to the general machine-shop problem.

Machines for punching and shearing, while usually arranged for constant speed, frequently require an adjustable-speed drive. For example, assume a punch operating at 28 strokes per minute. The operator may have work of such a character that he can easily punch a hole each stroke, while in another case, due to heavier sheets or greater accuracy required, he is compelled to skip every other stroke, punching but 14 holes a minute, while if the machine would permit he could readily do 28. Such a saving on this class of machinery usually yields a large actual return as the time required for setting up or making ready is, as a rule, small.

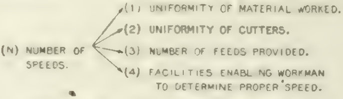

(R) RANGE IN SPEED.
(1) IF WORK ROTATES – RATIO OF MAXIMUM TO MINIMUM DIAMETERS OF WORK.
(2) IF CUTTERS ROTATE – RATIO OF MAXIMUM TO MINIMUM DIAMETERS OF CUTTERS.
(3) RATIO OF HARDEST TO SOFTEST MATERIALS WORKED.
(4) KIND OF OPERATIONS – WHETHER CUTTING, FILING OR POLISHING.

Factors That Influence Range of Speed.

Fig. 5.

The *amount* of horse power required for machines of different types depends on the factors given in Fig. 7.

I have given the principal items to consider when designing or selecting machine drives, but to more fully explain the line of reasoning that should be followed, I shall assume definite conditions, and consider the equipment needed to fulfill them.


(N) NUMBER OF SPEEDS.
(1) UNIFORMITY OF MATERIAL WORKED.
(2) UNIFORMITY OF CUTTERS.
(3) NUMBER OF FEEDS PROVIDED.
(4) FACILITIES ENABLING WORKMAN TO DETERMINE PROPER SPEED.

Factors That Influence Number of Speeds.

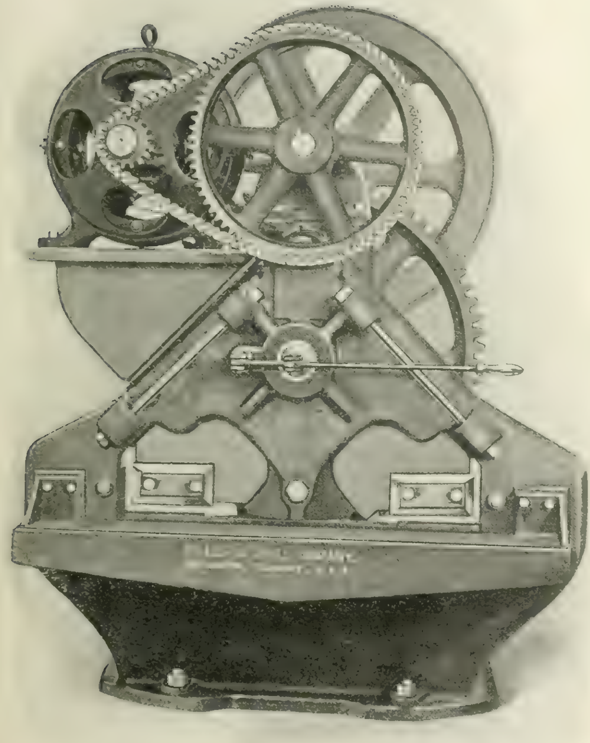
Fig. 6.

EXAMPLE.

LATHE........ for general work in shop of A. ——— B. ———. Company, manufacturer of air compressors.

General features of this plant and its organization that influence type of drive (see Fig. 1).

E.B.—1. The machine under consideration is to run in an old plant, hence no saving in cost of buildings could be effected by type of drive.



MOTOR-DRIVEN SHEAR.

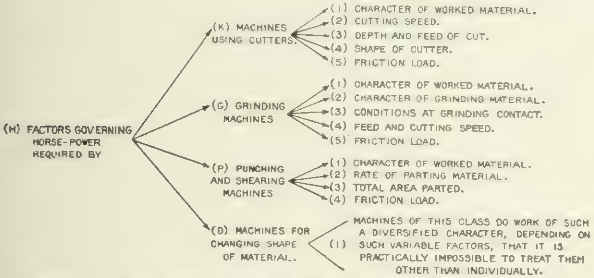
Morse Chain Company.

E. B.—2. The natural light at point where lathe is to be located is very poor, and it is important not to obstruct it any more than absolutely necessary.

E. B.—3. Artificial light has in the past been supplied by independent company, but they desire to install a power plant that will take care of this feature as well as power. It is desirable to depend largely upon general illumination by arc lamps with incandescent lights for detail work.

E. S.—1-2, and E. T.—1. For roughing work the best alloy steels, forged, treated, and maintained by special department assuring uniformity and high efficiency, will be used.

E. L.—1, 2, 3, 4. Character of work necessitates constant use of power crane, making overhead belting and fixtures objectionable and difficult to provide for on account of location in main bay of shop. As cost of power in this plant amounts to less than 3 per cent of total cost of product, it is not a determining factor in character of drive.


(H) FACTORS GOVERNING HORSE-POWER REQUIRED BY
(K) MACHINES USING CUTTERS.
(1) CHARACTER OF WORKED MATERIAL.
(2) CUTTING SPEED.
(3) DEPTH AND FEED OF CUT.
(4) SHAPE OF CUTTER.
(5) FRICTION LOAD.
(G) GRINDING MACHINES
(1) CHARACTER OF WORKED MATERIAL.
(2) CHARACTER OF GRINDING MATERIAL.
(3) CONDITIONS AT GRINDING CONTACT.
(4) FEED AND CUTTING SPEED.
(5) FRICTION LOAD.
(P) PUNCHING AND SHEARING MACHINES
(1) CHARACTER OF WORKED MATERIAL.
(2) RATE OF PARTING MATERIAL.
(3) TOTAL AREA PARTED.
(4) FRICTION LOAD.
(D) MACHINES FOR CHANGING SHAPE OF MATERIAL.
(1) MACHINES OF THIS CLASS DO WORK OF SUCH A DIVERSIFIED CHARACTER, DEPENDING ON SUCH VARIABLE FACTORS, THAT IT IS PRACTICALLY IMPOSSIBLE TO TREAT THEM OTHER THAN INDIVIDUALLY.

Factors Governing Horse-Power Required for Different Types of Machines.

Fig. 7.

E. M.—2. The type of management being introduced at this plant should ultimately assure intelligent direction of work and proper use of equipment.

Referring to Fig. 2:

We find that this shop will come under the class indicated by the symbol W-2.

Referring to Fig. 4:

(A)—X-1-F-2. Majority of work (probably 80 per cent) will be steel and gray-iron castings between 18 ins. and 48 ins. diameter. Maximum conditions call for removal of same amount of metal between these limits, and approximately constant cutting speed. Maximum horse-power requirements are consequently constant through the range, but subject to fluctuations at any one point below the said maximum.

Referring to Fig. 5:

R—1. At times it will be necessary to machine work as small as 10 ins. diameter, or as large as 60 ins. diameter; consequently a range in speed of 5 : 1 would be required for this purpose.

R—2. Cutters will always be stationary.

R—3. The ratio of hardest to softest material required by specification will be approximately 2 : 1. This will increase the necessary speed range to 10 : 1.

R—4. The majority of work will be roughing and finishing with cutters. Some filing and finishing with emery cloth will, however, be necessary, and for this purpose experience would dictate a cutting speed of 150 ft. per minute on 10 ins. diameter. It will be necessary to provide a cutting speed of 15 ft. per minute on the largest diameter on account of the frail character and difficulty of driving some of the castings to be machined. Total range of speed is determined by limiting conditions of a cutting speed of 15 ft. per minute on 60-in. work and 150 ft. per minute on 10 in. work. I have purposely chosen these extreme conditions to better illustrate my point. In practice a 60-in. lathe is seldom required to run at 57 r.p.m.

$$\frac{150}{\frac{10 \times 3.14}{12}} = 57.3 \text{ r.p.m.}$$

$$\frac{15}{\frac{60 \times 3.14}{12}} = .95 \text{ r.p.m.}$$

Consequently, for all practical purposes, the face plate of the lathe should run from one revolution per minute to 57 revolutions per minute.

Referring to Fig. 6:

N—1. It was stated above that the character of material would vary in the proportion of 2 : 1, this being a requirement of the products manufactured. Uniformity of material, or how nearly the requirements can be attained under shop conditions, is one of the factors influencing the number of face-plate speeds.

A fully-equipped laboratory, under the direction of an able chemist, who has entire charge of the cupolas and Bessemer steel converters, assures a much more uniform product in the plant in question than is usually the case. A great deal of experiment and investigation will be necessary however, before we can make definite assertions in this direction, but castings from the same pattern should not vary more than 20 per cent.

N—2. Cutter of the character indicated above (E.S.—1) should not vary in efficiency more than 10 per cent.

N—3. The full consideration of this point involves an understanding of the laws governing speed, feed, and cut for various materials. It will not be practical to include here full data on this detail. Hundreds of tons of steel and cast iron have been cut up to determine these relations, and constant experiment is necessary to keep abreast of rapid improvements. I will only say that it is quite as necessary to provide an adequate number of feeds as it is spindle-speeds, and in fact a limited number of either one of these factors will give efficient results provided a very close regulation can be had on the other.

In the present instance it was not considered advisable to specify changes to the standard feeding mechanism, as this feature had been well taken care of by the builder.

N—4. As the operation of the machine is ultimately governed by the facilities at the disposal of the machinist who runs it, it is absolutely essential that this point be given most careful study. It involves practically every feature of shop system and management, and it is only under such systems as that developed by Mr. Fred W. Taylor, of which functional foremanship is but a single detail, that the conditions, as outlined above, can be fulfilled. It necessitates that the operator of the machine be informed as to the character of the material, efficiency of the cutter, proper cutting speed in consideration of duration of cut, and many other equally important factors.

So it will be seen that we cannot arrive at any data which would enable us to specify definitely the number of spindle-speeds required. Our conclusions must necessarily be based principally on experience in shop practice, and for this reason engineers differ widely in their views. For the example under consideration, speeds increasing in increments of 15 per cent are, in our estimation, quite as close as can be used to advantage. It is well, however, to err on the safe side, providing too many speeds rather than too few.

Referring to Fig. 7:

H. K.—1, 2, 3, 4. Maximum permissible cutting speed on steel castings will be 60 ft. per minute; on gray-iron castings 60 ft. per minute (determined by actual requirements on a large variety of work). Maximum cut, cast-steel, $\frac{3}{8}$ in. deep, $\frac{1}{16}$ in. feed; gray-iron, $\frac{3}{8}$ in. deep, $\frac{1}{16}$ in. feed. (These conditions are established by character of work.)

The experiments conducted to determine the laws governing speed, feed, and depth of cut, for various materials referred to above (*N—3*) have been made available for purposes of design by means of slide rules, based on the derived empirical formulæ.

For the depth of cut and feed under consideration (cast-steel), the calculated pressure on the tool would be: 5,550, or horse-power required $= \frac{5550 \times 60}{33,000} = 10.1$ hp.

H. K.—5. The friction load can only be arrived at through experience and depends not only on the machine, but character and method of driving work. Experimental data on machines quite similar to the one under consideration would indicate 3 horse-power through the entire range as sufficient to allow for this purpose.

These conditions are plotted in Fig. 8. It will be noticed that the horse-power falls off on either side of the working part of the scale.

While it is easy to theorize as to the horse-power required for work of various diameters, in actual practice the conditions are about as I have shown. It must be borne in mind that the machine under consideration should be primarily adapted for the majority of work that it will handle. We have assumed that 80 per cent of this will be between 18 ins. and 48 ins. in diameter, so that work outside of these limits is the exception. On small work, such as would be handled, there is not likely to be opportunity for as heavy roughing cuts, and castings over 48 ins. in diameter cannot be swung over the carriage, nor would it be good policy to aim at high efficiency at this point for the additional cost would not be justified by the saving effected on such a small fraction of the total output.

As the horse-power between the working limits shown above was figured for the maximum cutting speed of 60 ft. per minute, we can plot a relation between revolutions per minute and horse-power. (See Fig. 9.) The selection of electrical equipment for this lathe will be taken up further on.

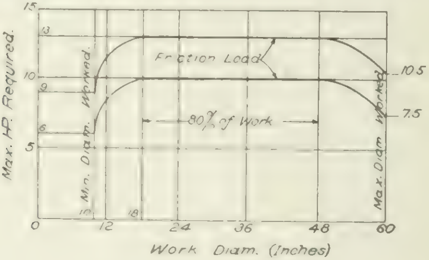


Fig. 8.

The analysis of conditions presented above is, as was stated, essentially a problem for the machine builder to work out in other words, the electrical companies should look to him for general specifications covering motors and controllers.

When equipping machines of old design with motor drive, or remodeling them to better their efficiency, each one should be considered separately with regard to the special line of work it handles. As manufacturing becomes more specialized it will be possible for the builder of machines to design with more intelligence, for he can then treat a type as we have treated an individual.

To avoid repetition, I will assume the following conclusions have been established.

(1) Machines of present design of comparatively small work, requiring constant-speed drive should, in most instances, be grouped

and operated from motor-driven line shafts. Specifications for new machines for such duty should be made with a view to special requirements. Indirect savings in one plant may much more than offset additional cost of constant-speed motor on each machine, while this would not be true in another.

(2) For group driving, both direct- and alternating-current motors give thoroughly satisfactory results. In either instance, if properly installed, repairs should not be an important feature. In certain industries—the textile mills for example—the induction motor has decided advantages on account of close-speed regulation with varying loads and lessened fire risk, but for machine shops these features are unimportant.

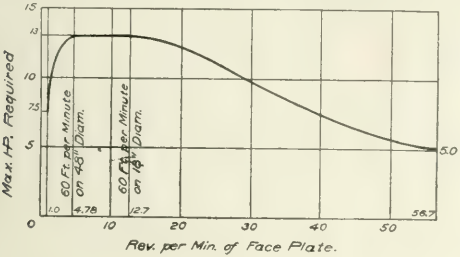


Fig. 9.

(3) Mechanical means of speed control, including step cone pulley and variable-speed countershafts, while suited for certain specific cases, do not meet the general requirements of machine drive. An attempt to obtain the necessary speeds by gearing, for example, is not only costly (if a sufficient number of changes are provided), but inefficient, in that as a rule, the machinery must be stopped to change from one speed to another, and cannot be controlled from an independent point.

(4) For adjustable speed work, direct-current motors only give satisfactory results at the present time. It is not practical by this means to use a range greater than 6 to 1, while in the majority of cases 3 to 1 gives the most economical results. In other words, in most instances, it is necessary to resort to a combination of mechanical and electrical control, the disadvantages of

each being largely eliminated by this means. For example, even where machines are handling a very general line of work, the greater part of it will be covered by a range of 3 to 1, so that if this amount is obtained electrically, gear changes will be seldom necessary, and at the same time a comparatively inexpensive motor required. Consequently the lathe requirements specified above are of quite as much value to the man who designs the mechanical features of the machine as the one who furnishes the electrical apparatus.

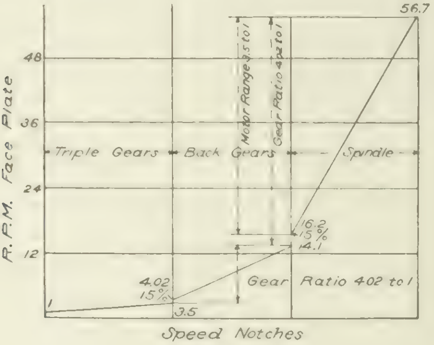
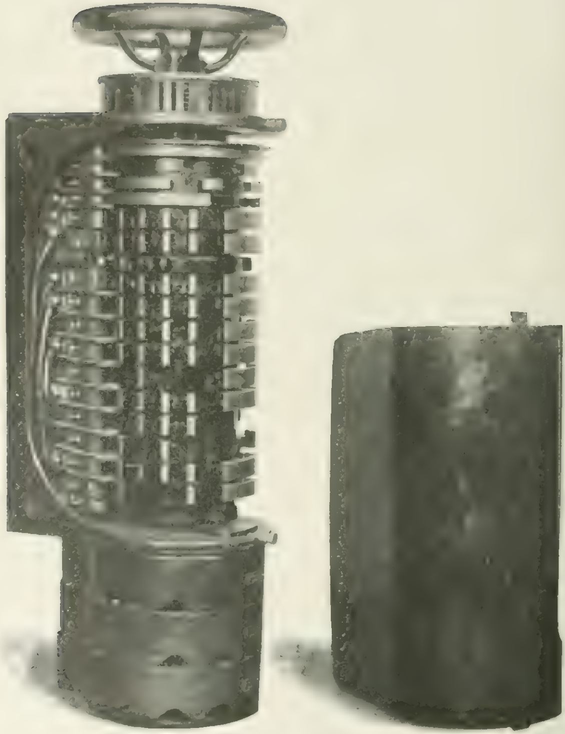


Fig. 10.

(5) Long transmission lines may make alternating-current desirable, and, for certain extended plants, the best results can be obtained by its use, together with motor-generator for direct-current variable-speed motors. If, however, but one kind of current will be available, decision should be largely governed by number of individual drives required. In many instances, while group drives may be desirable at the start, new equipment should be purchased with individual motors for the sake of adjustable speed and ease of control.

Returning to the 60-in. lathe considered above, the total speed range of 57 to 1 can be covered by the usual triple gear arrangement, with the resulting ratios shown on the chart. The range in motor speed, of 3.5 to 1, is quite practical and can be taken care of by any one of the systems referred to above.



MULTIPLE-VOLTAGE CONTROLLER.

Crocker-Wheeler Company.

I shall not dwell upon the strictly mechanical details of the drive, rather assuming that this part of the work is properly taken care of, but pass on to a consideration of the motor-drive systems.

(2) NOTES ON MOTOR-DRIVE SYSTEMS.

Systems now on the market for obtaining adjustable speed by means of motor drive, and advocated by prominent manufacturers, are given below:

(1) Field weakening only

(2) Double commutator motor combined with field weakening.

(3) Edison three-wire system combined with field weakening

(4) Unbalanced three-wire system combined with field weakening.

(5) Four-wire multiple-voltage system combined with field weakening.

There are two classes of purchasers, with widely differing requirements, and to whom different systems appeal:

(1) The customer who buys motors for his own use to equip machines already in operation, or special machinery which must be given individual consideration.

(2) The customer who buys for an unknown third party. The builder of machines, for example, who manufactures his product without any knowledge as to whom the purchaser may be, and consequently must design equipments that will meet conditions existing in plants where his product is solicited.

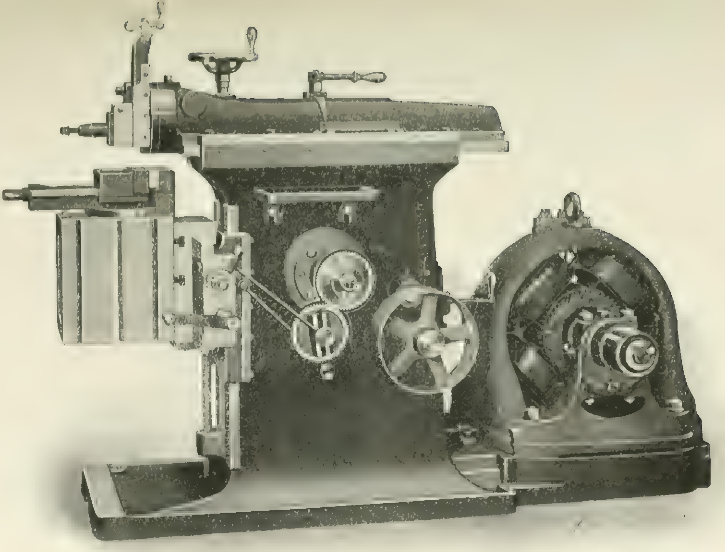
The electrical manufacturers have been slow in realizing this almost self-evident classification. The very essence of modern manufacturing consists in specialization, as it is only in this way that cost can be reduced to a minimum. Such establishments must be classified under the second division referred to above, and the product considered as a *type*, while in the first class given machines or given establishments can be treated separately.

Conditions in the past have in either case demanded a separate consideration of drive for practically every customer, on account of special character and numerous types of motor-drive equipment, but substantial progress, as far as the machine builders are concerned, will not be made until their product is manufactured complete in every essential. This means the adoption of a motor that can be operated on 110 or 220 volts, direct current, as one of these is not only found in nearly every large establishment, where it is used for cranes and lighting, but in many of the small shops.

The three- and four wire systems, on the other hand, have been installed by a very small percentage of the shops who are, from time to time, purchasing new equipments, hence for commercial reasons such apparatus does not appeal to machine builders. It may, however, possess distinct advantages to purchasers of the first class who contemplate the motor equipment of an entire shop, either at once or as conditions demand. As they can exercise the greatest freedom in selection of equipment for motor drive, I shall consider the systems enumerated above from their standpoint. It will then be a comparatively simple matter to apply these conclusions to the more special conditions which must be met by the machine builders.

All customers, unless they employ consulting engineers, are called upon to decide themselves upon the system to adopt, and, as their experience does not, as a rule, cover the details of electrical engineering, they must depend largely on the statements put forward by electrical companies.

There is no doubt that the manufacturers in many instances have taken advantage of the special character of machine work to rate their motors in a way that is very deceptive. The words "full load" are almost universally abused, and as there is no standard specification adhered to, the only safe basis for comparison is through a knowledge of the weight and maximum speed for a given horse power through a given range, with the understanding that a specified overload must be carried at any point for a certain time. Such an analysis would, according to the views of the various builders, give at least an intelligent idea of the equipment required to fill a definite need, but in a number of instances our experience has indicated that claims made by leading manufacturers have not been fulfilled in actual test. Machine-tool duty unquestionably permits of a different basis of rating from constant horse-power work in much the same way that street railway motors are rated on a basis of their own, but when one manufacturer adheres strictly to a rating of present standard, and another departs from it without the knowledge of the customer, the latter is likely



CRANK SHAPER. DRIVEN BY VARIABLE SPEED MOTOR.
Cincinnati Shaper Co.

to be comparing bids on two radically different equipments. This we have repeatedly found to be the case. We feel that this matter should be given careful consideration by such a body as the American Institute of Electrical Engineers and a definite understanding arrived at.

I shall assume general familiarity with the systems under consideration. In general, a motor for a given maximum speed and a given range, to deliver a given horse-power through this range, will be at least as large when operated by field weakening only, as when a combination of either two or more voltages with field weakening is adopted. Unless the motor is specially designed for field weakening, it will be larger than in the latter case. We have been unable to obtain any satisfactory data from the engineering departments of electrical manufacturers concerning variation of horse-power with field strength, so prefer to base our conclusions upon tests which we have conducted in connection with work for various clients.

As the cost of variable-speed motors and auxiliary power transmission equipment, such as chain or gears, is in proportion to the speed at which it operates, we should see that the latter is as high as is consistent with the various engineering considerations. A number of the manufacturers of motors do not give sufficient thought to the adaptation of motor speeds to available means of transmitting power to the machine. There are three methods in common use, namely: leather belts, gears (including worm and spiral gearing) and chain. While the great flexibility of the belt, in relieving the machine of sudden jar, has distinct advantages in certain instances, gears and chain are used in the majority of cases for individual drive.

(1) FIELD WEAKENING (WITH A SINGLE VOLTAGE).

A number of manufacturers have recently placed on the market motors designed to run on a single voltage, but that may be varied in speed by means of field weakening over a range, in some cases, as high as 6 to 1. Until recently, ranges as great as the above have not been considered practicable and our tests of motors of various makes have indicated that in this respect much can be accomplished through careful motor design. Manufacturers that adhere to the simple shunt type do not advocate, except for special work, a range exceeding 4 to 1, while others who have adopted either additional poles or special windings claim to have eliminated the difficulties usually encountered, and are prepared to furnish motors giving any variation desired. These types, however, have not been in operation a sufficient length of time to enable us to confirm their statements.

We have found that customers are frequently misled concerning the size of frame required for a given duty for motors operating on this system. As the horse power that can be developed with a given frame is in proportion to the speed of the armature, it is necessary to use, for a range of 4 to 1, a motor frame rated at least four times as large as the power required if practical speeds are not to be exceeded. Even such a frame will not, in most cases, make it possible to rate the motor as liberally as is the case with standard constant speed apparatus, as the exceptionally strong field required is likely to cause heating at the slow speed, and at the high speed the weakened field will cause poor commutation.

We have not yet experimented with a motor of this type that would operate continuously under the full-load current at its highest speed without giving some trouble at the commutator. It is true, as was stated above, that such conditions would rarely be met in the machine shop, but to purchase with intelligence it is necessary to know how much manufacturers depend on this fact. Motors with a range of 3 to 1 have already been successfully applied to machines requiring a comparatively small amount of power, although, as will be pointed out later, the apparatus has not been perfected as fully as is the case with other systems.

If the lathe considered above be equipped with apparatus operating on this system, the relation between motor horse-power and that required by the machine, shown in Fig. 11, should fulfill the conditions satisfactorily, as the upper curve is drawn through maximum values, and when they are reached the overload on the motor would only be 30 per cent.

Referring to the dimensions and ratings furnished by one of the manufacturers, whose apparatus has shown up very favorably under test, we find that a motor weighing 1,615 lbs. will deliver 10 horse-power between a range of 350 r.p.m. and 1,050 r.p.m., or one weighing 2,300 lbs. will deliver 10 horse-power between 225 r.p.m. and 900 r.p.m. We recommend the use of the last frame, as satisfactory commutation should be assured by the smaller speed range, namely, 225 r.p.m. to 787 r.p.m.

(2) DOUBLE COMMUTATOR MOTOR (COMBINED WITH FIELD WEAKENING).

The additional cost of the double commutator motor, together with the maintenance of two commutators instead of one, are objections to this system that, in our estimation, offset its advantages for other than special cases.

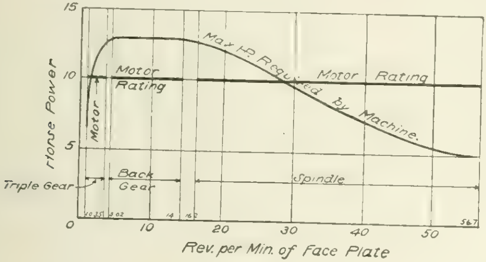


Fig. 11.

(3) EDISON THREE-WIRE SYSTEM.

The combination of the Edison three-wire system with field weakening permits of a range of 4 to 1, with but 100 per cent increase in speed by the latter means, and, consequently, eliminates commutator troubles to a marked extent.

The balanced three-wire system has been adopted quite generally in the past for lighting purposes, and may be obtained either by means of standard generator, together with a separate balancer, or by providing the former with slip rings connected to an autotransformer from the middle point of which the neutral is taken. The latter arrangement is advocated by manufacturers of this apparatus.

The selection of motor to operate on three-wire system for the 60-in. lathe should be based on curves shown in Fig. 12. The same assumptions are made regarding overload as in the former case.

The motor required for these conditions, according to one of the principal advocates of the Edison three-wire system, would weigh 2,600 lbs. and operate from 220 r.p.m. to 880 r.p.m.

(4) THE UNBALANCED THREE-WIRE SYSTEM.

The unbalanced three wire system was developed to give, with a minimum size motor, a range somewhat greater than 6 to 1.

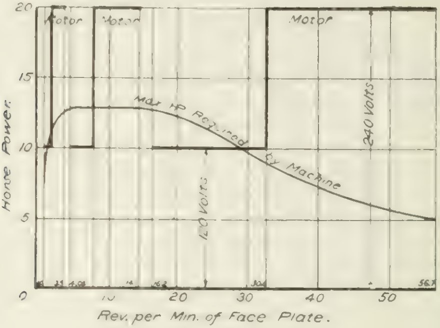


Fig. 12.

For a range of 4 to 1, or under, it has no advantage over the balanced three-wire system, nor does it possess the several good features of the one last named.

(5) FOUR-WIRE MULTIPLE VOLTAGE SYSTEMS.

The principal advantage of the multiple-voltage system is that absolutely standard motors (the same as are used for constant-speed duty) are used with perfectly satisfactory results. This is not true of any of the other systems. Motors designed to operate on a three-wire system must run with full field, full voltage at about half the speed of a constant-speed motor for the same duty, therefore cannot be economically used for the latter purpose. This is true to a still greater degree for motors designed to give a wide range of speed by means of field weakening only.

The maximum range in speed obtainable by the system under consideration depends upon the voltages adopted and the amount the field is weakened, but for purposes of economy, except where constant torque is required, the working scale is usually confined to the higher voltages. The lower voltages, while used chiefly for starting, prove of great assistance at times for setting up work.

The two systems which have been advocated differ in that one requires an arithmetical series of voltages, and the other a geometrical series. In either case a balancer, or specially designed generator, is required to give the voltage referred to and four wires employed for distribution. These two features are frequently cited as disadvantages that more than offset the good points of this system, but, in reality, they do not complicate matters to any great extent nor add materially to the cost of a large installation.

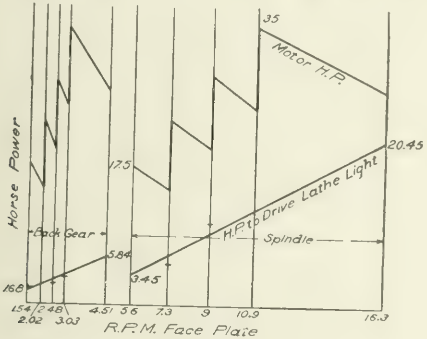


Fig. 13.

While, as stated above, the average machine tool may be considered as requiring constant horse-power through its working range, in numerous instances, particularly when dealing with large machinery, we find that requirements call for an increased horse-power with an increased speed. For such cases the multiple-voltage system is most desirable as is clearly shown by the curves in Fig. 13.

This data relates to a large gun lathe, driven by multiple-voltage apparatus. The lower curves are drawn through points determined by actual test and show the power required to drive the lathe with face plate in place, but otherwise running light. The power available for useful work is represented by the vertical height between the curves just referred to and the upper ones, which show the relation between horse-power and speed of a standard 35 horse power Crocker Wheeler motor. Such examples are, of course, exceptional.

Thus far, I have assumed the use of the same range in motor speeds, when operating on the spindle, backgear, and triple gear, and in the case of field weakening motors, or those operating on a balanced three-wire system and rated as above there would not be any advantage in doing otherwise. The characteristics of the multiple-voltage system, however, are such that a smaller motor can frequently be used. The gear ratios are determined by the nature of the load curve. This fact was borne in mind when plotting the curves shown in Fig. 14 relative to multiple-voltage equipment for lathe A.–B. Company.

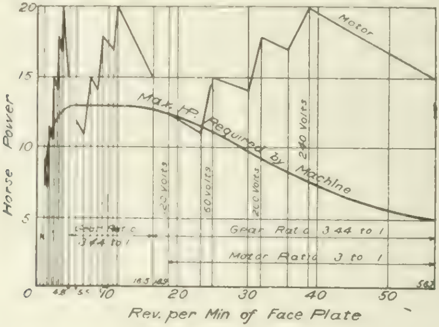
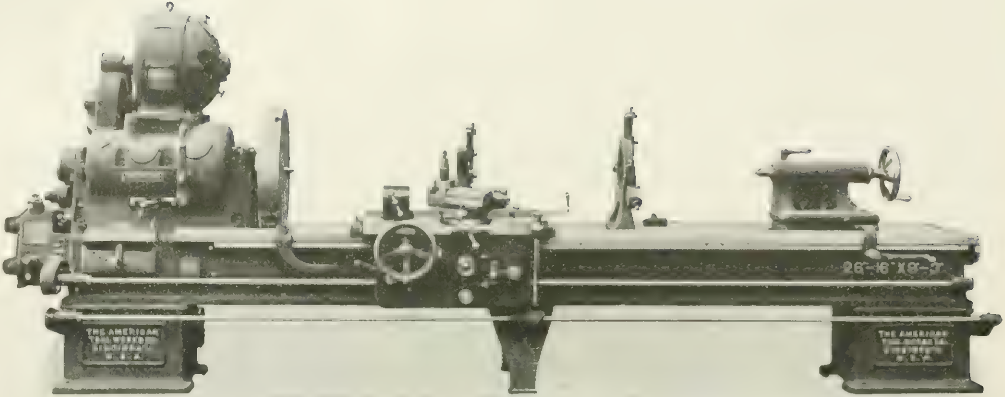


Fig. 14.

A motor weighing 2,350 lbs. and operating from 236 r.p.m. to 820 r.p.m. is recommended by one of the leading manufacturers of this apparatus. They prefer to rate their motors very conservatively, which accounts for the decrease in horse-power with field weakening. By actual test their motors stand up under these conditions as well as many other makes that are said to deliver constant horse-power through a range of 2 to 1.



LATHE EQUIPPED WITH CROCKER-WHEELER MULTIPLE-VOLTAGE APPARATUS.

Controller Arranged so that the Operator Can Start, Stop and Obtain Any Spindle Speed Within Range of Motor, without Leaving His Work.

(3) NOTES CONCERNING DIFFERENT MAKES OF APPARATUS.

In every instance final decision must rest with the perfection of apparatus. One of the most important details so far as efficient shop use of the motor drive is concerned is the controlling mechanism. For machine-shop duty thoroughly rugged and compact controllers are required. No contacts should be exposed as is now the case with the apparatus furnished by a number of manufacturers of field weakening motors. With thoroughly efficient apparatus it is practically impossible to damage either the motor or controller by the rapid operation of the latter. I do not mean by this that it is well to swing the controller handle suddenly from the off position to the full-speed point, but such action should not result in destructive sparking at the commutator or arcing at the controller points.

The satisfactory operation of a controller for the conditions under consideration depends largely upon the success with which the manufacturer has fulfilled the following conditions:

(1) Controllers should be completely inclosed in iron casing.

(2) It should be impossible through the manipulation of the controller to stop the motor at any place on the scale other than the off position.

(3) Rapid operation of the controller should not cause serious damage to either motor or controller.

(4) They should be so designed that they can be easily operated from a convenient point on machine.

(5) A sufficient number of speeds should be provided, depending on machine requirements.

(6) Controllers that require frequent operation must be designed with liberal contact surface and more rugged in every respect than those used principally as "speed setters," and as a result only operated at intervals.

(7) The design should permit of repairs with the greatest ease. In this connection the location and type of resistance grids should be given careful consideration.

(8) Each speed should be clearly defined either by a star-wheel and pawl or other means.

A number of manufacturers have placed on the market controllers that are giving good results, and in most respects comply with the above requirements.

Motors have been designed to accompany these controllers that are well suited for application to machines, in so far as their external dimensions are concerned, but at the same time we feel sure that the electrical manufacturers who are willing in certain cases to depart from present designs will gain a strong position with the machine builders.

(4) CONCLUSIONS.

In all probability a paper such as I have prepared for this meeting of electrical engineers, would have seemed decidedly out of place some years ago. I have dealt with matters which would then have been considered the business of the machine builder or mechanical engineer, and not requiring the thought and study of the electrical profession. It is now realized, however, that the motor drive problem presents many new features, and is a distinctly different one from the manufacture and sale of standard generators, for example. The earning power of the latter is largely dependent upon the design and workmanship, features that can be passed upon before the machinery leaves the works. If a power plant is found to be too small, more units can be readily added without in any way interfering with those in use. On the other hand the earning power of a motor equipment for individual operation of machines depends largely on conditions over which the manufacturer has no control. The continued growth of this department of his plant, however, is governed by results actually obtained with his product under working conditions, so to protect himself he is called upon to see that the proper equipment is selected, and if possible, advise as to it's use. As far as the customer is concerned, it would usually be better for him to close his eyes and grasp any one of possibly four makes of apparatus, devoting his time to its proper installation and operation, rather than reversing the process as is so often done.

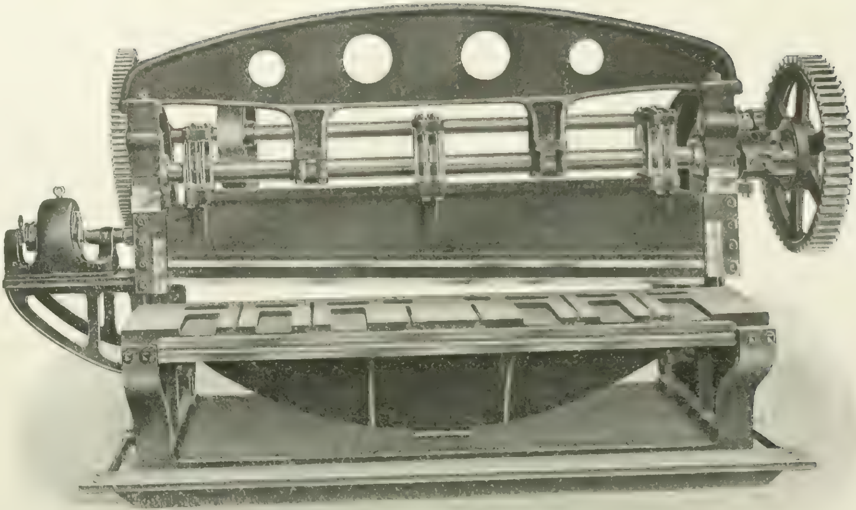
The conclusions reached above concerning the motors required for the 60-in. lathe are summarized in the table below:

	Weight.	Min. R.P.M.	Max. R.P.M.
Field weakening	2,300	225	787
Three-wire system	2,600	220	770
Four-wire system	2,350	235	820

It must be remembered that the ability of these motors to fill the imposed conditions was not determined by actual test, the data being the recommendations of well-known electrical companies who manufacture the respective types of apparatus. These figures should at least make it clear that many statements constantly made concerning the size of motor required for a given horse-power and speed range cannot be other than erroneous.

I pointed out above the conditions which must be met by the machine builder necessitating the selection of a type that does not require for its operation special auxiliary apparatus. While motors operating on two wires and giving a range as high as 4 to 1 by means of field weakening do not at present give as good all-round results as those operating on the multiple-voltage and three-wire systems, we feel that their adoption by the manufacturers referred to is certainly justified. When this is more fully appreciated the electrical companies should rapidly achieve better results in this direction.

The customer purchasing for his own use should, on the other hand, *differentiate clearly between the machine builders' requirements and his own*, for in many cases he can secure more satisfactory results, all things considered, through the adoption of a system combining with field weakening a number of voltages

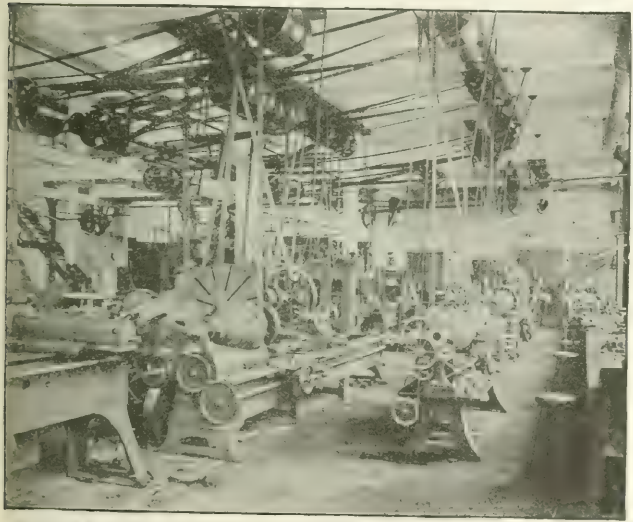


GUILLOTINE SHEARS. MOTOR DRIVEN.

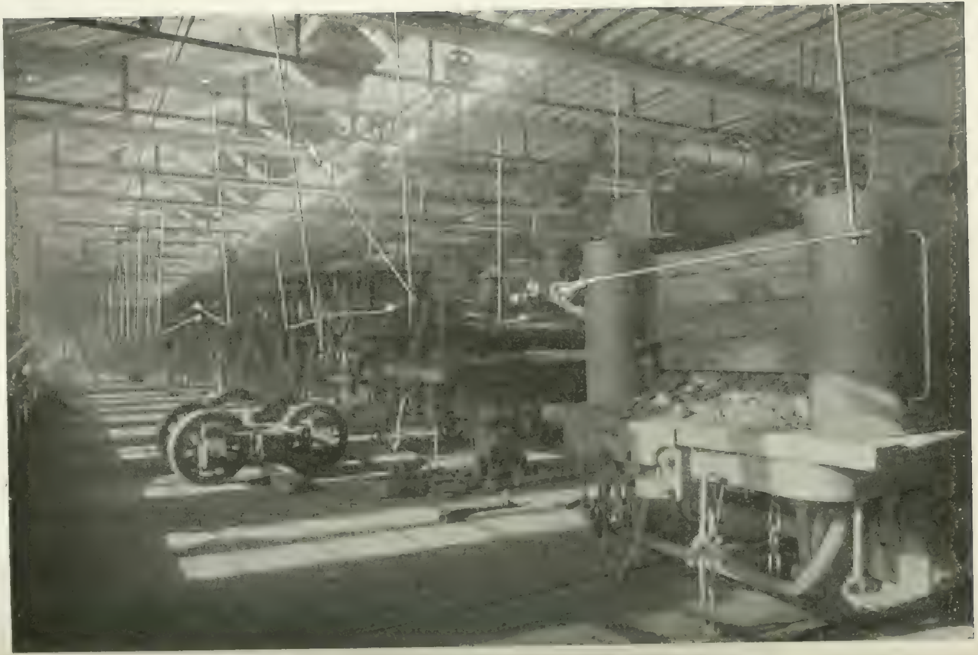
Erie Foundry Company.

SHOP LIGHTING.

It is only within a few years that what is now regarded as proper attention to lighting has been considered in the design and construction of factory buildings. Formerly, a shop seemed to be designed more to protect the tools and materials from the weather, than to afford any degree of convenience or comfort for the workmen. It is now regarded as good business policy (in other words, it pays) to provide buildings which are properly heated, lighted, and ventilated. In such buildings, it has been found that workmen are more content, do better work, and produce more. From the old-fashioned blacksmith shop, in which each smith was supposed to work by the light of his own fire, it is a far cry to shops such as those of the National Cash Register Company at Dayton,



BOSTON & ALBANY RAILROAD MACHINE SHOP, WEST SPRINGFIELD, MASS.
Equipped with White Adjustable Fixtures.



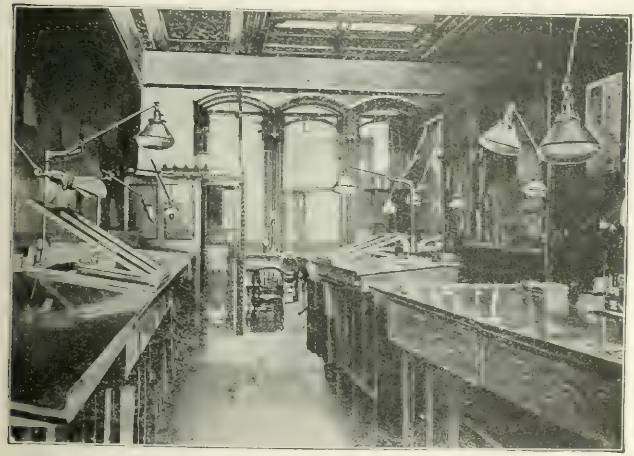
INTERIOR OF REPAIR SHOP, BOSTON AND ALBANY R.R., ALLSTON, MASS.

Incandescent Lights with White Adjustable Fixtures

Ohio, in which the comfort and convenience of the employees has been given a degree of attention that seems to the old shop managers to partake of the nature of coddling.

DISTRIBUTION OF SUNLIGHT.

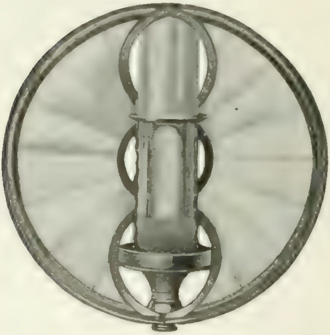
In considering this question of lighting, it is well understood that daylight is the best light, especially when it is not accompanied by the direct rays of the sun. To properly distribute daylight—which is, of course, the cheapest light—over large areas, is the first problem to be considered in the design of new shop buildings. This may be accomplished in a number of ways. Where buildings are several stories in height, and where light, except in the upper story, must be admitted from side windows, those windows should reach from the top of the bench to the ceiling. A given amount of glass arranged in this manner gives a much better general distribution of light than the same amount of glass put into the ordinary form of short windows. The amount of light in the center of the room depends very largely upon the height of the windows at the side. All modern factory buildings



WHITE ADJUSTABLE FIXTURES IN WORCESTER SAFE DEPOSIT & TRUST COMPANY, WORCESTER, MASS.

are now lighted by long, narrow windows. The common type of shop, consisting of an open floor with a gallery on both sides, is usually lighted, in addition to the tall side windows, by glass in the sides of the monitor roof. If these monitor windows are kept clean, they add greatly to the light of the main floor.

The best system of roof lighting is by means of what is termed a "saw-tooth" roof, the short and comparatively steep side of the tooth being composed wholly of glass. This glass should face as nearly north as possible, in order to avoid the direct sunlight. In this connection, it will be remembered how the workmen of the old school, especially if employed on work requiring close application, always selected a north window, even if the view therefrom was not so pleasing as that from some other point of the compass. This saw-tooth roof may be used on the top of a monitor in place of side windows, and it results in a much better lighted floor.


WELSBACH BURNER.
With silvered glass reflector.

Old shops, in which a change in amount or location of glass area is impossible, can have their light increased in amount and better distributed by a judicious arrangement of machines, and, particularly, by keeping the walls and ceilings as nearly pure white as possible. Whitewash is so cheap and so easily applied by modern pneumatic methods, that there is little or no excuse for neglect in this particular. Whitewash can easily be made so that it will not readily rub off, in fact, so that it can be washed; but in most cases a fresh application is preferable to cleaning The removal of all possible belting (which can be accomplished by electric driving, either individually or by the group system) adds largely to the lighting effect, and also, by the suppression of dust and flying oil, keeps the walls and ceilings in much better condition. Some factories carry this whitening effect to the point of having the machine tools painted white and varnished. This not only avoids dark spots in the room, but shows plainly any neglect of machinery. In a shop equipped in this manner, the dirty and slothful workman is entirely out of place, and he usually changes his habits or seeks some other shop where his natural conditions prevail.

ARTIFICIAL LIGHTING.

Artificial lighting, which is usually required in northern latitudes, may be divided into three classes: General lighting, individual lights, and portable lights.

Lighting by candles, except in some cases of portable lights, has entirely disappeared; but many country shops still have to depend upon oil as an illuminant. In such cases, large lamps of the Argand type are suspended from the ceiling for general illumination, and small flat-wick lamps, preferably on swinging wall brackets, are used for the individual. The quality of this illumination depends, first, upon the care of the lamps, and, second, upon the quality of the oil. Oil lights at best are dirty and entail a large amount of labor. They are objectionable in that they must be kept from draughts of air, which smoke the chimneys, and thus the shop is often deprived of proper ventilation.

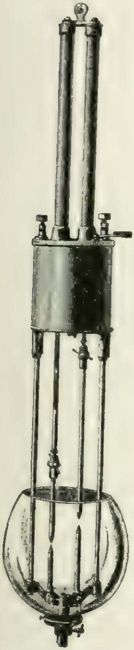
Gas is more frequently used for shop lighting than any other artificial illuminant. It may be classed under the heads of oil gas, coal gas, natural gas, and acetylene. For the isolated shop, oil gas and acetylene are particularly adapted, as such gas plants are easily installed and require but little attention. In every case, the gas plant should be entirely separate from the factory building, and preferably under ground. While acetylene furnishes a light almost ideal in character, it is particularly poisonous, although leakage is readily detected by its odor. A more serious drawback is that this gas forms violently explosive compounds when mixed with air in comparatively small proportions. Many serious and some fatal accidents have occurred by failure to realize the importance of this fact. These installations should be made only by those thoroughly familiar with the subject, and their use must be carefully guarded.

Coal gas is very largely used for shop lighting, on account of its comparative cheapness and the fact that, even in small cities, it can be readily obtained. As it is also used in many shops for heating, in connection with the Bunsen burner and blowpipe, it serves a double function which renders it peculiarly adapted for factory purposes. The ordinary open fish-tail burner, consuming about six cubic feet per hour, is the type of burner generally used. This light is objectionable on account of the fact that it vitiates the air; this, in the winter months when the windows are closed, becomes a serious matter, and calls for largely increased ventilation. The light flickers, even in still air, which makes it very trying to one's eyes when engaged on fine work, and this difficulty is further increased by currents of air caused by open windows or moving belts.

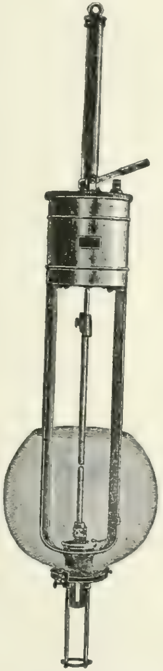
ORDINARY WELSBACH BURNER.

THE WELSBACH BURNER.

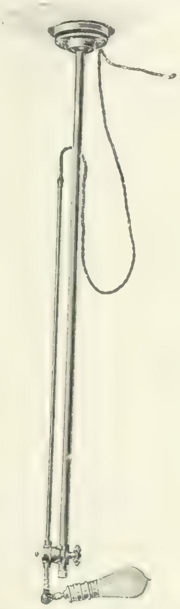
Ordinary illuminating gas used in connection with a Welsbach burner, furnishes a very steady light with about one-half the gas consumption necessary for the open light. The Welsbach light is best suited for general lighting, where two or more burners are contained in the same globe and suspended from the ceiling. As an individual light, the Welsbach is not in great favor, on account of its ghastly color combined with a faint tinge of green, which renders it objectionable to many workmen. The mantle used in the Welsbach light is extremely fragile, and it is quickly put out of commission by shocks, vibration, and air currents. For these reasons it is not so well suited for use in the shop as it is for domestic purposes. The Welsbach light, however, is not dependent upon the illuminating quality of the gas, but upon the incandescence of the mantle which may be produced by any form of fuel gas without the enriching necessary to make it suitable for use in an open burner. Natural gas, therefore, which is used for heating in many sections of the country, can also be used for lighting if employed in the Welsbach burner. As this gas is very cheap, it often pays to use it in this manner.



Open-Arc Lamp, Double.
Old Style.



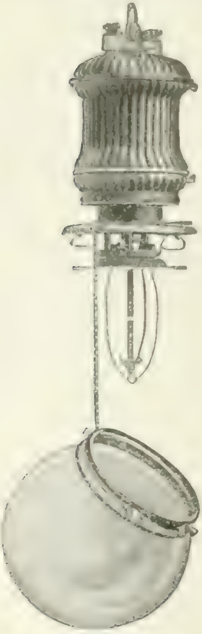
Open-Arc Lamp, Single
Old Style.



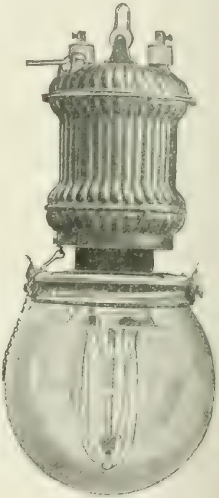
White Adjustable Ceiling Fixture for Incandescent Light. Style A.

ELECTRIC LIGHTING.

Electric lighting is rapidly being introduced for shop purposes, especially when the current is generated in the factory. The arc light is commonly used for general illumination, and the incandescent light for the individual. The open arc light is being supplanted by the enclosed arc, with a distinct gain in economy and safety. The open arc, even with the best quality of carbon, is somewhat noisy, and is subject to disagreeable flickering, while the falling of pieces of incandescent carbon, is not only annoying, but dangerous. The enclosed arc light requires less frequent trimming, is more steady, and owing to the fact that it is enclosed, it absolutely prevents danger from falling particles of carbon. Arc lights for general illumination are usually in the vicinity of 1,200 candle-power.



Enclosed Arc Lamp.
Globe in Trimming Position.



Westinghouse Series Alternating
Enclosed Arc Lamp.

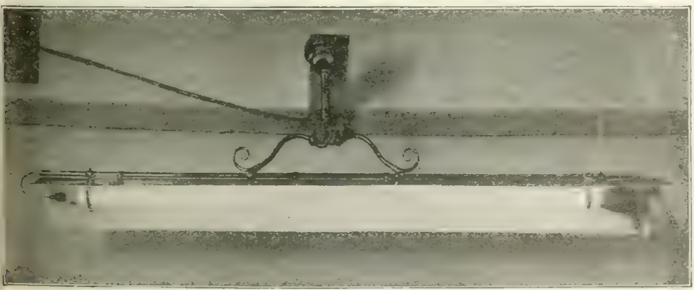
The 16-candle-power incandescent lamp is generally used for individual light ; but the 8-candle-power lamp, with a suitable reflector, is less dazzling and furnishes all the light necessary. The

White Adjustable Bench Fixture
Incandescent Light. Style D.

system adopted in some drafting rooms, of using an inverted arc—that is, one with the crater in the lower carbon—combined with a reflector to throw the light directly to the ceiling, results in a uniformly diffused light. This avoids the sharp shadows cast by the direct light from the arc, and has much to recommend it as a shop light, especially if the ceilings and walls are kept white.

There are several styles of fixtures used in connection with the incandescent light to place the lamp in any desired position, as the ordinary drop light is very inconvenient in this particular. The White fixture, with its ball-and-socket joint, is one of the best.

In connection with the question of electric lighting, the necessity of maintaining a constant voltage is one that is not given the


COOPER HEWITT LAMP FOR GENERAL INTERIOR LIGHTING.
Type H 7, an improved form of Type V 5. Can be operated in horizontal, vertical or inclined position.

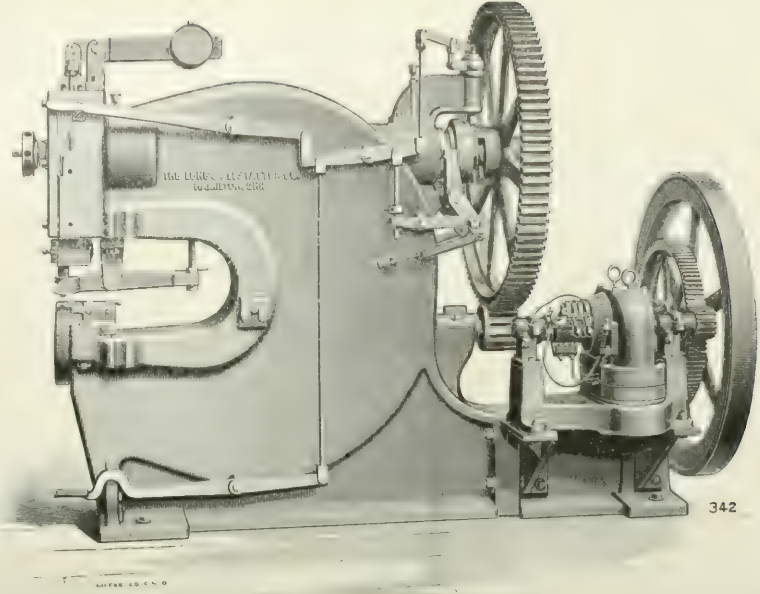
attention it deserves. It is almost impossible to secure satisfactory lighting from a generator driven by the main engine, and this is especially true if electric cranes are also operated from this generator. In the best practice it is considered necessary to have a separate engine and generator to be used solely for the lighting system. A generator driven by the main engine is found satisfactory for crane service.

Cooper Hewitt Lamp for Interior Lighting where Moderately Strong Illumination is Desired.

Designed for series installation two in series on 100 to 120 volts direct current. Suspended at an angle of 20 from ceiling or fastened to wall. Type H 6.

The Cooper Hewitt Light. The Cooper Hewitt mercury vapor lamp is the cheapest form of electric lighting, and will undoubtedly be the commercial light for factory use, especially in shops doing a fine class of work. The color of this light, due to the total absence of red rays, is objectionable but not injurious; and further experiments will undoubtedly produce a light based on this principle which will meet many requirements

For portable lighting, there is nothing at present superior to the incandescent lamp, for, by means of a long flexible cord, it can be taken to any position. The incandescent lamp, furnished with a magnetic base, can be attached to any iron or steel surface, where it will remain until the light is extinguished. For erection work, particularly, this type of lamp is peculiarly adapted.



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MOTOR-DRIVEN PUNCH.

The Long and Allstatter Co

FORGING.

Forging in general treats of the hammering, working, or forming of heated metals.

The Materials upon which the work of forging or blacksmithing is done, are wrought iron and steel. As explained in "Metallurgy," wrought iron is an iron from which "the silicon phosphorus and most of the carbon has been removed." Steel usually contains some of the impurities that are characteristic of cast iron with the marked peculiarity of holding a varying percentage of carbon. Mild steels are so called on account of the small amount of carbon which they contain. As the percentage of carbon increases, it becomes more difficult to weld the metal. Greater care must also be used in heating lest the metal be burned and its strength destroyed. Until recently all heavy forgings involving welding, were made of wrought iron, but now it is customary to make most forgings of mild steel, particularly large ones, although wrought iron is somewhat more satisfactory where a great amount of welding is required.

These metals may be roughly divided into three general classes; although the division line may not be sharply drawn between any two classes, the classes being *Wrought Iron*, *Machine Steel* and *Tool Steel*. The characteristics and method of manufacture of the three metals are described in "Metallurgy." A rough distinction such as a blacksmith would use is about as follows: *Wrought Iron* has a fibrous structure with stringy streaks of slag running lengthwise of the bar giving it a decided fibre, similar to wood. *Machine Steel*, more properly described as mild steel, or sometimes called soft steel, has much the same properties as wrought iron excepting that it lacks the fibre and is somewhat stronger. *Tool Steel* differs from the other two materials in the fact that by suddenly cooling from a high heat it may be made very hard, or hardens, as the technical term is. Wrought iron or machine steel are not hardened by the same treatment. Tool steel is practically the same thing as wrought iron or machine steel with a small percentage of carbon added. In fact, either of the two metals may be turned into tool steel by the addition of carbon. This principle is used in case hardening. Norway iron or Swedish iron is a grade of very pure wrought iron containing little slag. It is more expensive than ordinary wrought iron. Refined iron is a grade of wrought iron not as good as Norway iron but better than ordinary iron. Norway iron costs about twice as much as machine steel, which is somewhat cheaper than wrought iron of almost any grade. Machine steel, made by both the open-hearth and Bessemer processes, is used for forging.

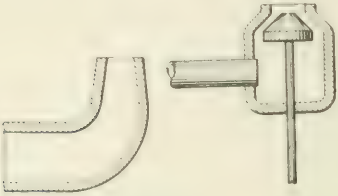


Fig. 1.

EQUIPMENT.

The equipment of the forge shop consists in general of a forge in which the metals are heated, an anvil for resting the metals on while hammering, and the various tools as described below for shaping and working.

The Forge. While forges or fires are of many shapes and sizes the principles of their construction remain the same. An ordinary blacksmith forge is a fireplace in the bottom of which there is a tuyere for admitting a blast of air to blow the fire. Where the air blast is furnished by a hand bellows, the pipe leading therefrom to the tuyere is open throughout. Where a power-driven blower furnishes the blast, there is a valve in the pipe for regulating the same.

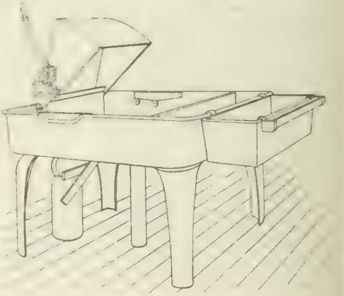


Fig. 2.

The usual form of tuyere consists of a single blast pipe, opening into the bottom of the fire pit. This may be a simple nozzle as in Fig. 1, with the blast regulated by a damper in the pipe; or, it may have a regulator at the mouth of the tuyere as shown. Sometimes the tuyere has several openings, and is then in the form of a grate. Whatever its form, it should be possible to clean it from below, in order that coal and clinkers falling into it may be removed.

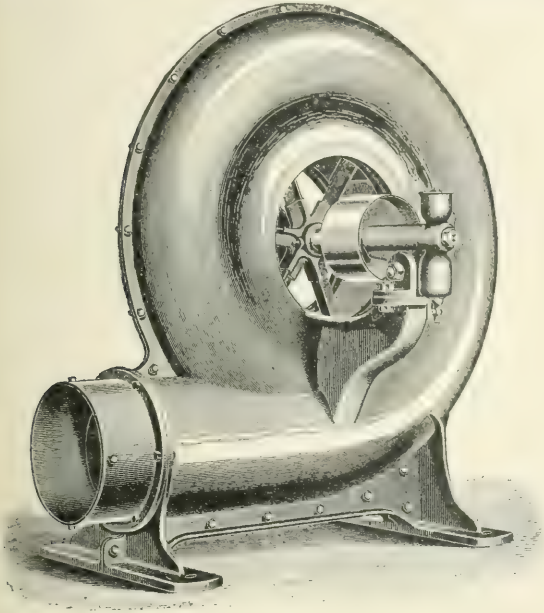


Fig. 3.

A modern type of forge is shown in Fig. 2. This is provided with a hood for carrying off the smoke. The pipe connected to the hood extends downward to an underground flue leading to an exhaust fan which draws out the air. The blast pipe is also underground, and a small pipe leads upward to the tuyere, the amount of blast admitted to the fire being regulated by a slide in this pipe. This system of underground piping is known as the "*Down Draft*" system.

In some shops no provision is made for carrying off the smoke, while in others hoods are placed above the forges and connected to overhead pipes, which may be either connected to an exhaust fan or led directly to the roof. The "Down Draft" system is the more modern and generally the best.

The Blast is furnished to the fires of a blacksmith shop by blowers of various kinds. For many years the ordinary bellows was used. This has been superseded by the fan blower which is now almost universally used, even for hand power.

Such a fan blower is shown in Fig. 3. It is formed of a thin cast-iron shell in which there are a set of rapidly revolving blades. These blades set up a current of air which presses against the side of the shell and escapes through the tangential opening. The pressure of the blast used for an open blacksmith fire varies from about 2 to 7 ounces per square inch. The lower pressure is used for a light fire and light work. The higher pressure is suitable for heavy classes of work.

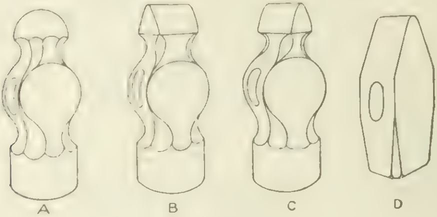


Fig. 4.

Hammers. Several kinds of hammers are used in a forge shop. The commonest shape is the *ball pene* shown at A, Fig. 4. Other kinds are the *straight pene* and *cross pene* illustrated at B and C. A *square faced* hammer sometimes called a blacksmith's hammer, is shown at D. This is occasionally used on tool work. Commonly a ball pene hammer of about a pound and a half weight is used.

In the fitting of the handle to the head great care should be taken. Hammer handles are made elliptical in cross section. The major axis of this ellipse should exactly coincide with that of the eye of the head. The reason is that the hand naturally grasps the handle so that its major axis lies in the direction of the line of motion. Hence, unless the handle is properly fitted in this particular, there will be constant danger of striking a glancing blow. The handle should also stand at right angles to a center line drawn from the ball of the pene to the face. The eye in the head is usually so set that the weight on the face side is greater than that on the pene. The effect of this is to so balance the tool that heavier and more accurate blows can be struck than if the weight were evenly balanced on each side of the eye.

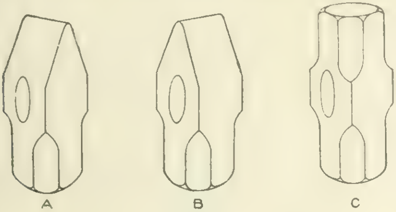


Fig. 5.

Sledges are heavier hammers used by the blacksmith's helper and vary in weight from five to twenty pounds. The three common shapes are shown in Fig. 5; A, B, and C being *cross pene*, *straight pene* and *double faced* sledges respectively. A sledge for common work ordinarily weighs about 12 pounds. Sledge handles are generally about 30 to 36 inches long, depending on the nature of the work to be done.

Anvils. Next to the hammer in importance is the anvil. This may be any block of metal upon which the piece to be shaped is laid. The anvil must be of such a weight that it can absorb the blows that are struck upon it without experiencing any perceptible motion in itself.

The ordinary anvil, Fig. 6, has remained unchanged in form for many hundreds of years. As now made, the body *a* is of wrought iron to which a face of hardened steel is welded. From one end there projects the horn *b*, and the overhang of the body at the other end *c*, is called the tail. At the bottom there are four projections *d*, called the feet, which serve to increase the base upon which the anvil rests as well as to afford the means for clamping it down into position. In the tail there is a square and a circular hole. The former is called the hardie hole, the latter the spud hole.

An anvil of this form serves for the execution of any work that may be desired.

Anvils are also made with a body of cast iron, to which a face of steel is welded.

The anvil should be placed upon the end of a heavy block of wood sunken into the ground to a depth of at least two feet, so that it may rest upon a firm but elastic foundation. As the anvil is subjected to constant vibrations, by the nature of the work, it is necessary that it should be firmly fastened to the block.

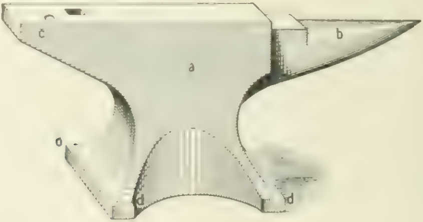


Fig. 6.

Anvils are classed and sold by weight. The weight is generally stamped on the side of the anvil. Three numbers are used. The first to the left shows the weight in cwt. of 112 pounds each. The middle number shows the additional quarters of cwt. and the right hand figure the number of odd pounds. For instance, an anvil marked 2-3-4 would weigh 2 × 112 + ¾ of 112 + 4 lbs. = 312 lbs. and would be known as about a 300-pound anvil. Anvils are sometimes made of special shapes, but the one here shown is the common one.

Tongs. Next to the hammer and anvil in importance and usage are the tongs. They vary in size from those suitable for holding the smallest wires to those capable of handling ingots and bars of many tons in weight. The jaws are also adapted to fit over the piece to be handled and are of a great variety of shapes. As the

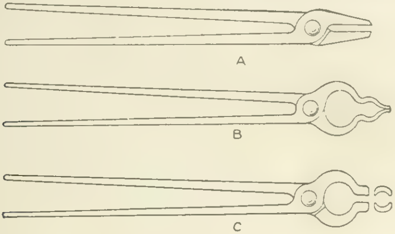


Fig. 7.

requirements of each piece of work varies so much from that which precedes and follows it, it is customary for the blacksmith to dress his own tongs and adapt them, from time to time, to the work he has in hand. Comparatively few, therefore, of the various shapes of tongs found in shops are manufactured and for sale. A few of the general types and forms in common use are here given.

A, Fig. 7, shows a pair of *flat-jawed* tongs, the commonest shape used. B is a pair of *pick-up* tongs used for holding work while tempering, and picking up pieces of hot metal. C is a common shape used for holding both square and round iron, the jaws being bent to fit the stock in each case. A modification of this shape is also used for heavy steam hammer work. Tongs frequently have the jaws made in some special shape for a particular piece of work, the object always being to have the jaws grip the work as firmly as possible.

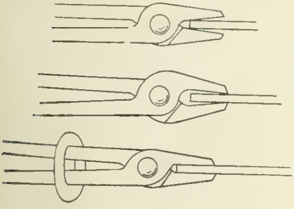


Fig. 8.

Fitting Tongs. Tongs must be always carefully fitted to the work. Tongs which take hold of the work as shown in Fig. 8, should not be used. The first pair shown have the jaws too close together, the second, too far apart. When properly fitted the jaws should touch the work throughout the entire length as shown in the lower sketch. To fit tongs the jaws are heated red hot, the piece to be held placed between them, and the jaws hammered down until touching their entire length. Tongs which do not fit the work perfectly should never, under any circumstances, be used. When in use on all but the smallest work, a link is driven over the handles to grip the tongs in position as shown.

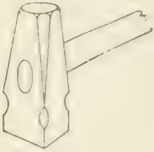


Fig. 9.

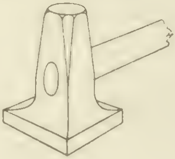


Fig. 10.

Set Hammers and Flatters are used for smoothing off flat work when finishing. The *set hammer*, Fig. 9, is used for working up into corners and narrow places. The *flatter*, Fig. 10, is used on wide flat surfaces. The face of the set hammer used on light work is generally about 1¼ inches square. That of the flatter about 2½ inches square, although the sizes vary depending upon the kind of work.

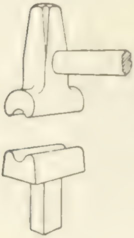


Fig. 11.

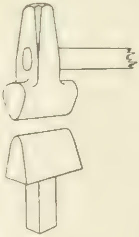


Fig. 12.

Swages, shown in Fig. 11, are used for finishing round and convex surfaces. The upper tool is known as the top swage and is provided with a handle. The lower one is the bottom swage and is held in place by a square stem or shank which extends downward and fits into the hardie hole of the anvil. Tools of this character should never be used on an anvil where they fit so tight that it is necessary to drive them into place. The swages shown here are used for round work. Swages are also made for octagonal, hexagonal and other shapes.

Fullers, used for working grooves or hollows into shape, are also made top and bottom as shown in Fig. 12. The top fuller is for finishing into round corners, around bosses, and on the inside of angles as illustrated later on. The fuller is also used to spread metal, when it is wished to work the metal only in one direction. The metal spreads at right angles to the working edge of the fuller.

Swage Blocks, a common sort of which is shown in Fig. 13, are used for a variety of purposes mostly for taking the place of bottom swages. These blocks are commonly made from cast iron and weigh about 150 pounds.

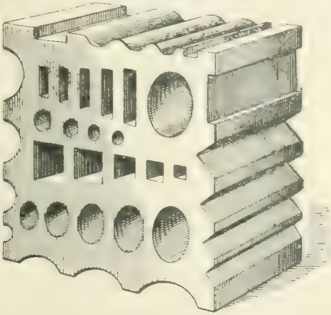


Fig. 13.

Other Tools. The tools used commonly are calipers, a carpenter's two-foot steel square, dividers, a rule, shovel, tongs, ladle, poker and a straight bar for loosening the fire. In addition to the ordinary calipers, a blacksmith usually has a pair of double calipers similar to those shown in Fig. 14. With these, two dimensions may be used, one side being set for the thickness, and the other for the width, of the material. When several measurements are to be made particularly on large work, a strip of light stock about $\frac{1}{8}$-inch by 1 inch wide is used. The different dimensions are laid off on this with chalk or soapstone. In use the strip is held against the work and used in the same manner as a rule. A light rod having a small bent end, made by bending over about $\frac{1}{2}$ inch of stock at right angles, is also sometimes used, particularly when working under the steam hammer. The dimensions may be laid off from the inside of the hooked end. When in use the hooked end is pulled against the end of the material. Soap-stone crayon is ordinarily used for marking on iron. The marks do not burn off, but will not show at a red heat. Marks to show at a high heat must be made by nicking the corner of the bar with a chisel or by marking with the center punch. Another common way of making measurements on hot material is to lay off the different distances on the side of the anvil with chalk, the dimensions being laid off from one corner or end.

Fuel. The common fuel for small fires is "soft" or bituminous coal, coke for large fires and furnaces, and occasionally hard coal in small furnaces. The soft coal used is of a grade known as smithing coal. It should be very clean and free from impurities. A lump of good forge coal breaks easily with a crumbly looking fracture and the coal shows clean and bright on all faces. It will not break up into layers as "steaming" coal will, these seamy looking breaks being caused by the more or less earthy impurites. If forge coal splits and shows dull looking streaks or layers, it is poor coal. Good coal has little clinker and breaks easily. When used, the coal is dampened and kept wet before putting on the fire. It should be broken up fine before dampening, and not used in lumps.

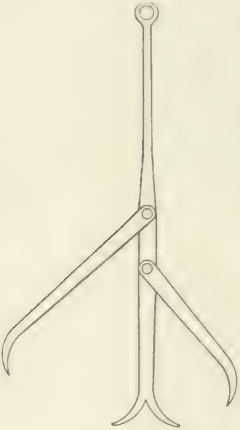


Fig. 14.

Fires. The fire must be carefully watched. It is very important that it should be in first class condition at all times for the work in hand. A certain depth of fire is always necessary. If the fire be too shallow, the cold blast will penetrate the fire in spots, making it impossible to heat the metal. There should be depth enough to the fire to prevent this. For small work there should be at least three or four inches of fire below the metal that is heating. There should also be thickness enough of fire above the work being heated to prevent the metal from losing heat to the outside air. The fire should be kept as small as possible to heat the work properly. As a general rule the fire will follow the blast. If the fire is wanted larger it may be made so by loosening the edges of the fire by a bar, allowing the blast to come through around the sides, causing the fire to spread. When a small fire is wanted the damp coal should be packed down tightly around the sides and the center of the fire loosened up slightly For light work a small round fire is used. For heavier heating the fire is started by placing a large block on top of the tuyere, on each side of which green coal is packed down hard in the shape of an oblong mound. The block is then removed and the fire started in the hole left. These mounds are left undisturbed and fresh fuel is added to the fire in the shape of coke which has either been previously made by loosely banking a quantity of green coal over the fire and partially burning it to coke, or is bought ready made. With a small fire the fuel is constantly added around the sides where it is turned into coke. This coke is raked into the center of the fire as wanted and more coal added around the sides and patted down to keep the fire in shape.

Oxidizing and Reducing Fires. When too much blast is blown through the fire all the oxygen is not burned out of the air. This attacks the iron, forming a heavy coat of oxide, or scale, (the black scale which falls from heated iron). This sort of a fire is known as an oxidizing fire and should not be used when it is possible to avoid it. When just enough air is being admitted to keep the fire burning brightly and all of the oxygen is burned, the fire is in good condition for heating. Very little scale is formed and some of the scale already formed may even be turned back to iron. This sort of a fire is known as a reducing fire. In other words, when the fire is in condition to give oxygen to anything, it is an oxidizing fire. If in condition to take away oxygen, it is a reducing fire.

Banking the Fire. The fire may be kept for some time by placing a block of wood in the center and covering over with fresh coal.

Stock. Material from which forgings are ordinarily made comes to the forge shop in the shape of bars having uniform sections throughout; generally round, square, or rectangular in section, and varying from $\frac{1}{4}$-inch thick to 18 inches square. Heavier sizes may be had to order. Bars are ordinarily 12 to 20 feet in length. Thin stuff, $\frac{1}{4}$ of an inch or less in thickness, usually comes in strips of about 40 feet. This may be had from stock up to six or eight inches wide. Tool Steel also comes in bars generally about six or eight feet long. The ordinary sizes of tool steel stock are known as base sizes and the price is fixed on these base sizes. Stock of a larger or smaller size than the base sizes is generally charged for at an increase in price. Thus inch square tool steel, which is a base size, is worth in certain grades about 14 cents a pound. Steel of exactly the same grade and character, $\frac{3}{16}$ of an inch square, costs about 18 cents.

WELDING.

If a piece of steel or iron be heated, as the temperature is raised the metal becomes softer. Finally a heat is reached, called the welding heat, at which the metal is so soft that if two pieces similarly heated be placed in contact, they will stick. If the pieces so heated be placed together and hammered, they may be joined into one piece. This process is known as welding. The greatest difficulty in welding is to heat properly, which must be done evenly and cleanly. If the temperature is raised too high, the iron will burn, throwing off bright star-like sparks. If the temperature be too low, the pieces will not stick to each other. The proper heat can only be determined by experimenting, which may be easily done by doubling over a piece of scrap iron for two or three inches and welding into a solid piece.

When heating wrought iron and mild steel, as the welding heat is reached, small particles of the metal are melted and blown upward from the fire by the blast. As these small particles come in contact with the air they burn and form small explosive sparks, like little white stars. Whenever these sparks are seen coming from the fire, it is a sure indication that the iron is burning. These sparks are sometimes used as a sort of an indication of the welding heat. The only sure way of determining the heat is by the appearance of the heated iron, which might be described as sort of creamy white. The welding heat is sometimes described as a white heat. This is not correct, as iron or steel is never raised to a white heat even when melted. This may be easily proved by comparing a piece of wrought iron at welding heat, with an ordinary arc lamp. When two pieces of metal are welded together there must be nothing between them. Heated iron or steel is always covered with scale (iron oxide). This scale, if allowed to stay on the surfaces to be joined, will prevent a good weld. It is necessary when welding, to heat the iron or steel to a high enough temperature to melt this scale and when the two pieces are put together, if the joint or scarf is properly made, most of this melted scale is easily forced from between the two pieces, leaving the clean surfaces of the metal in contact. This scale only melts at a very high heat, much higher than the heat at which it would be possible to weld the iron could it be kept free from scale.

Fluxes. These are used to lower the melting point of the scale. The flux is sprinkled on the surfaces to be joined just before the metal reaches the welding heat. The metal is then put back into the fire, raised to the welding heat and the weld made as usual. The scale is acted upon by the flux and melts at a lower heat than when no flux is used. As the flux melts it spreads, or runs, over the hot metal and forms a sort of protective covering, which, by keeping out the air, prevents to a large extent, the formation of more scale. The flux in no way acts as a cement or glue to stick the pieces together, but merely helps to melt off the scale already formed, and prevents the formation of more.

Sand and Borax. These substances are common fluxes. Sand may be used when welding wrought iron and machine steel; borax in place of sand for fine work and when welding tool steel. Borax is a better flux as it melts at a lower temperature than sand, and thus makes welding possible at a lower heat. Borax and salammoniac (ammonium-chloride) are sometimes mixed and used as a welding compound, or flux, the proportion being about four parts borax to one part salammoniac. This mixture is also a good flux for brazing. Borax contains a large amount of water which makes it boil and foam when melting and in this condition is very liable to drop away from the heating metal. If borax be heated red hot and allowed to cool, the water is driven off and the borax left in a glass like condition.

Borax treated this way and then powdered, is the best for welding, as it melts and sticks to the metal without any boiling.

Welding Compounds are fluxes serving the same purpose as sand or borax. Some of the better ones use borax as a basis. Some of these compounds are first class for their purpose and others are not as good, being simply intended as cheap substitutes for borax.

Fagot Weld. This is made by simply placing two or more pieces on top of each other and welding them in a lump or slab. Scrap iron is worked up in this way by making a pile six or eight inches square and eighteen inches or two feet long on a board, such as shown in Fig. 15. This pile is bound together with wires and placed in a furnace, fluxed with sand, and welded into a solid lump under a steam hammer. These lumps are afterwards worked out in bars or slabs by rolling or hammering. When a large piece is wanted, two or more of these bars are placed together and welded.

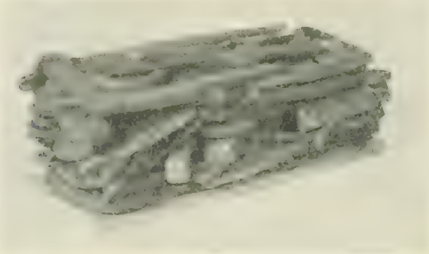


Fig. 15.

Scarfing. For most welding the ends of the pieces to be joined must be so shaped that when welded they will make a smooth joint. This shaping of the ends is known as *scarfing*, and the shaped end is called a *scarf*. The scarfed ends should not fit tightly before welding, but should be so shaped that they touch in the center of the joint, leaving the sides somewhat open. In this way when the weld is made, the melted scale is forced from between the pieces. If the scarfs were made to touch on the edge of the joint, leaving the center hollow, the scale not having a chance to escape, would be held in the center of the joint, leaving a weak place, and making a bad weld.

Lap Weld. This is the common weld used for joining flat bars together. The ends to be welded are scarfed or shaped as shown in Fig. 16. In preparing, the ends of the pieces to be welded should be first upset until they are considerably thicker than the rest of the bar. This is done to allow for the iron that burns off, or is lost by scaling, and also to allow for the hammering when welding the pieces together. To make a proper weld the joint should be well hammered, and as this reduces the size of the iron at that point, the pieces must be upset to allow for this reduction in size. For light work the scarfing may be done with a hand hammer. For heavy work a fuller and sledge should be used. After upsetting on light work, the end to be scarfed is roughly shaped with the pene end of the hammer as illustrated in Fig. 17, the final finishing being done with the flat face of the hammer.

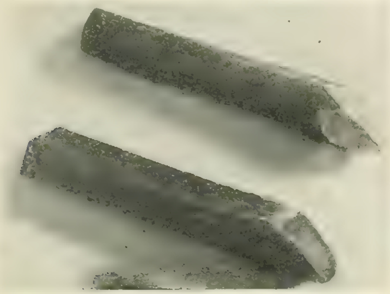


Fig. 16.

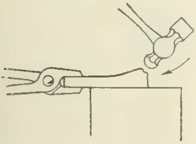


Fig. 17.

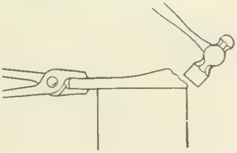


Fig. 18.

For this work (finishing the edge of the scarf) as well as all pointed work, the end of the bar should be brought to the extreme edge of the anvil in the manner indicated in Fig. 18. In this way a hard blow may be struck with the center of the face of the hammer without danger of striking the hammer on the anvil. For all ordinary lap welding the length of the scarf may be about 1½ times the thickness of the bar Thus on a bar ½-inch thick, the scarf will be about ¾ of an inch long. The width of the end, Fig. 16, should be slightly less than the width of the bar. In welding the pieces together the the first piece held by the helper should be placed scarf side up on the anvil and the second piece laid on top, scarf side down, overlapping them to about the amount shown in Fig. 19. As it is generally somewhat difficult to lay the top piece directly in place, it should be steadied by resting lightly against the corner of the anvil and thus "steered" into place.

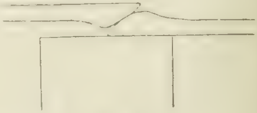


Fig. 19.

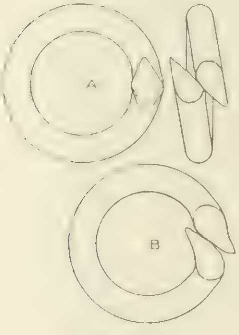
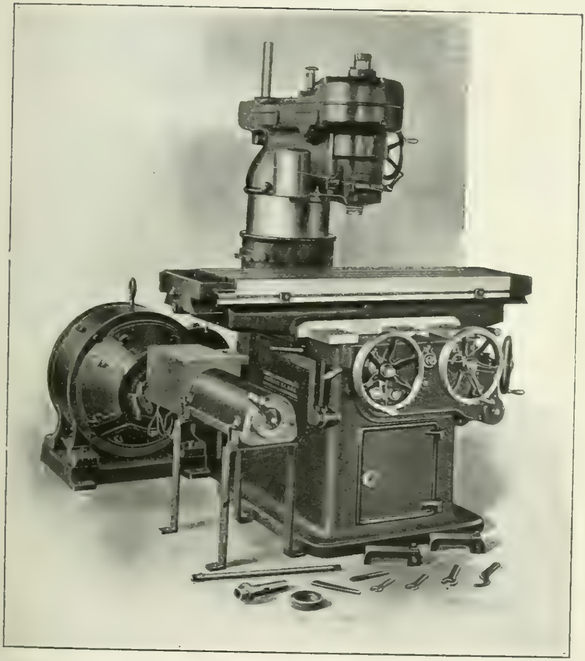


Fig. 20

Round Lap Weld. This is the weld used to join round bars end to end to form a continuous bar. All the precautions regarding the scarf, etc., used for making the lap weld should be taken with this as well. The general shape of the scarf is shown in Fig. 16. It will be noticed that the end is hammered to a sharp point. If the scarf be made with a flat or chisel-shaped end similar to the flat lap weld, the corners will project beyond the sides of the bar in welding and cause considerable trouble, as it will then be necessary to work entirely around the bar before the joint be closed down. With a pointed scarf the weld may be frequently made by hammering on two sides only. This is not so important when welding between swages.



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Ring Round Stock. When a ring is made, the exact amount of stock may be cut, the ends upset and scarfed as though making a round lap weld, the stock bent into shape as shown in Fig. 20 and welded. The ends should be lapped sideways as shown. In this position a ring may be welded by simply laying it flat on the anvil, while if lapped the other way, B, one end in, the other out, it would be necessary to do the welding over the horn of the anvil. In all welding the piece should be so lapped that the hammering may be done in the quickest and easiest manner.

Allowance for Welding. In work of this character when the stock is cut to a certain length, allowance is sometimes made for loss due to welding. The exact amount is hard to determine, depending on how carefully the iron is heated and the number of heats required to make the weld. The only real loss which occurs in welding is the amount which is burned off and lost in scale. Of course when preparing for the weld, the ends of the pieces are upset and the stock consequently shortened. The piece is still further shortened by overlapping the ends when making the weld, but as all of this material is afterwards hammered back into shape no loss occurs. No rules can be given for the loss in welding, but as a rough guide on small work, a length of stock equal to from $\frac{1}{4}$ to $\frac{3}{4}$ the thickness of the bar will probably be about right for waste. Work of this kind should be watched very closely and the stock measured before and after welding in order to determine exactly how much stock is lost.

Chain Links. The first step in making a chain link is to bend the stock into a "U" shape, care being taken to have the legs of the "U" exactly even in length. The scarf used is approximately the pointed shape used for a round lap weld scarf. An easy method of scarfing is as follows: One end of the "U" shaped piece is laid on the anvil as indicated in Fig. 21. This is flattened by striking directly down with the flat face of the hammer, the piece being moved slightly to the left, as shown by the arrow, after each blow, until the end is reached.

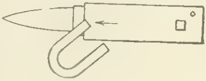


Fig. 21.

This operation leaves a series of little steps at the end of the piece and works it out in a more or less pointed shape as shown in

Fig. 22 at A. The point should be finished by placing it over the horn of the anvil and touching up with a few light blows. After scarfing the other end of the "U" in the same manner the ends are overlapped as indicated at B and welded together. The second link is scarfed, spread open, and the first link inserted. It is then closed up again and welded. The third is joined on this, etc. When made on a commercial scale, light links are not always scarfed but sometimes simply hammered together and welded in one heat. This is not possible in ordinary work.

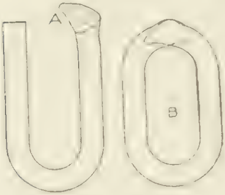


Fig. 22.

Band Ring. A method of making a band ring from iron bent flat ways is illustrated in Fig. 23. Stock is cut to length, the ends upset and scarfed, using a regular flat weld scarf, and the ring bent into shape and welded; the welding being done over the horn of the anvil. The heating must be carefully done or the outside lap will be burned before the inside is nearly hot enough to weld.

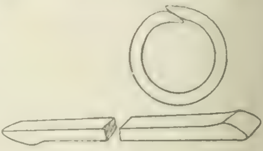


Fig. 23.

Flat or Washer Ring. This is a ring made by bending flat iron edgeways. The ends of the stock are first upset but not scarfed, except for careful work, the ring bent into shape, and the corners trimmed off on radial lines as shown in Fig. 24. The ends are then scarfed with a fuller or pene of a hammer and lapped over ready for welding as shown in Fig. 25

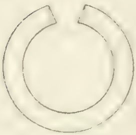


Fig. 24

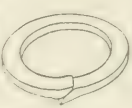
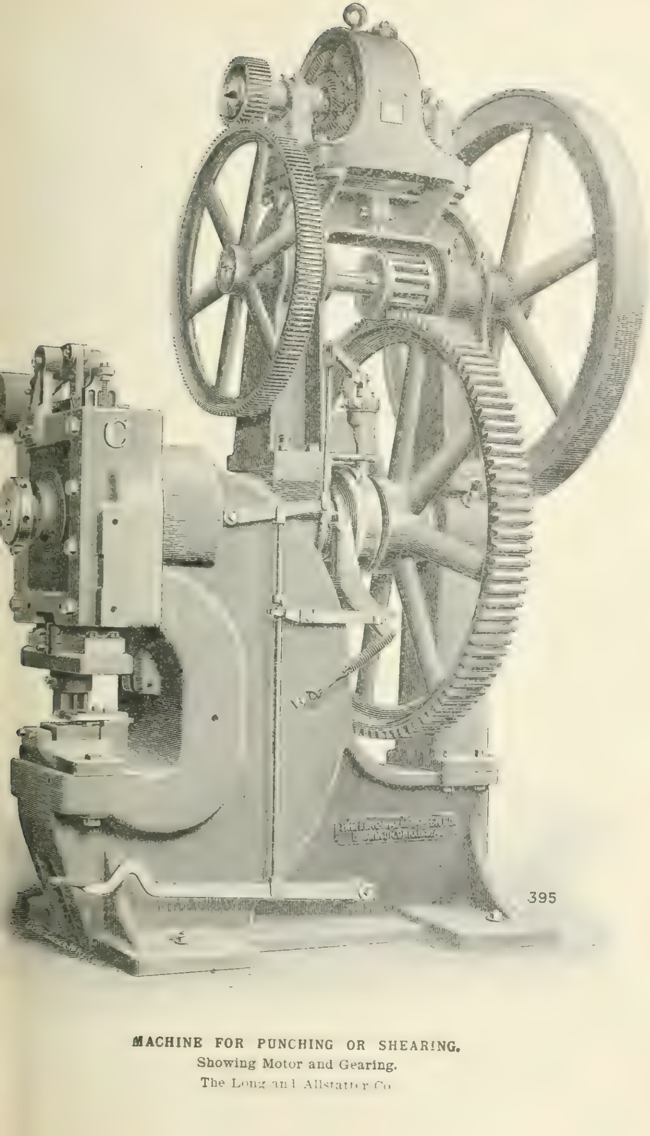


Fig. 25

Butt Weld. When pieces are simply welded together end to end making a square joint through the weld, it is known as a butt weld. It is best when making a weld of this kind to round the ends slightly as illustrated in Fig. 26. The ends are heated and driven together and this round shape forces



MACHINE FOR PUNCHING OR SHEARING.
Showing Motor and Gearing.
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out the scale and leaves a clean joint. As the pieces are driven together they are more or less upset at the joint, making a sort of a burr. This upset part should be worked down at a welding heat between swages. A butt weld is not as safe or as strong as a lap weld. Long pieces may be butt welded in the fire. This is done by placing one piece in the fire from each side of the forge. When the welding heat is reached the pieces are placed end to end, one piece "backed up" with a heavy weight, and the weld made by striking with a sledge hammer against the end of the other piece.

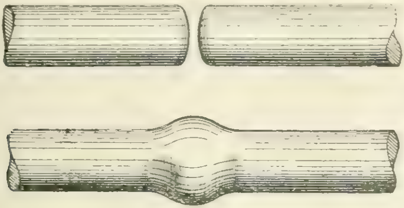


Fig. 26.

Jump Weld. Another form of butt weld shown in Fig. 27 is a jump weld which however is a form which should be avoided as much as possible, as it is very liable to be weak. In making a weld of this kind the piece to be butted on the other should have its end upset in such a manner as to flare out and form sort of a flange, the wider the better. When the weld is made, this flange may be worked down with a fuller or set hammer, thus making a fairly strong weld.

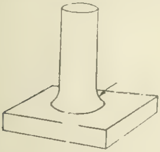


Fig. 27.

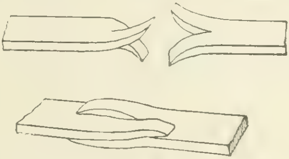


Fig. 28.

Split Weld for Thin Stock. Very thin stock is sometimes difficult to join with the ordinary lap weld for the reason that the pieces lose their heat so rapidly that it is almost impossible to get them together on the anvil before they have cooled below the welding heat. This difficulty is somewhat overcome by shaping the ends as shown in Fig. 28. The ends are tapered to a blunt edge and split down the center for half an inch or so, depending upon the thickness of the stock. Half of each split edge is bent up, the other down, the pieces are driven tightly together and the split parts closed down on each other as shown in Fig. 28. The joint is then heated and welded. This is a weld sometimes used for welding spring steel, or tool steel.

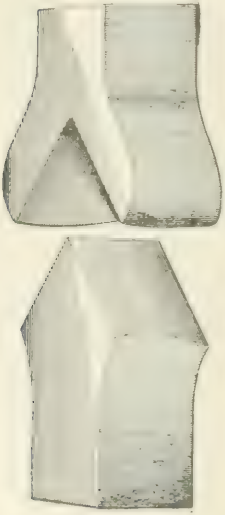


Fig. 29.

Cleft or Split Weld for Heavy Stock. Heavy stock is sometimes welded by using a scarf of the shape shown in Fig. 29. One piece is split and shaped into a "Y" while the other has its end brought to a blunt point. When properly shaped, the pieces are heated to the welding heat and driven together. The ends of the "Y" are then closed down over the other piece and the weld completed. A second heat is sometimes taken to do this. This weld is often used when joining tool steel to iron or machine steel. Sometimes the pieces are placed together before taking the welding heat.

Angle Weld. In all welding it should be remembered that the object of the scarfing is to so shape the pieces to be welded that they will fit together and form a smooth joint when properly hammered. Frequently there are several equally good methods of scarfing for the same sort of a weld, and it should be remembered that the method given here is not necessarily the only way in which that particular weld may be made. Fig. 30 shows one way of scarfing for a right angled weld made of flat iron. Both pieces are scarfed exactly alike, the scarfing being done by the pene end of the hammer. If necessary, the ends of the pieces may be upset before scarfing. Care should be used here as in other welds to see that the pieces touch first in the center of the scarf, otherwise a pocket will be formed which will retain the scale and spoil the weld.

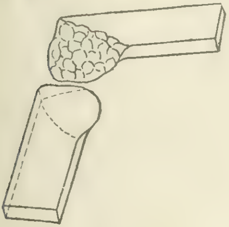


Fig. 30.

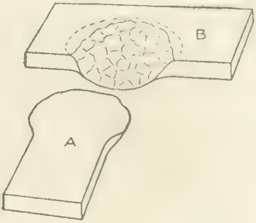


Fig. 31.

T-Weld. A method of scarfing for a T-weld is illustrated in Fig. 31. The stem A should be placed on the bar B, when welding, in about the position shown by the dotted line.

T-Weld Round Stock. Two methods of scarfing for a T-weld made from round stock are shown in Fig. 32. The scarfs are formed mostly with the pene end of the hammer. The illustration will explain itself. The stock should be well upset in either method.

Welding Tool Steel. The general method of scarfing is the same in all welding but greater care must be used in heating when welding tool steel. The flux used for welding tool steel should be the salammoniac and borax mixture mentioned before. Spring steel or low carbon steel may be satisfactorily welded if care is used. To weld steel successfully the following precautions should be observed. Clean the fire of all cinders and ashes. Put sufficient coal upon the fire so that it will be unnecessary to add more coal while taking the welding heat. Upset both pieces near the end and scarf carefully. When possible, punch a hole and rivet the two pieces together. Heat the steel to a full red heat and sprinkle with borax. Replace in the fire and raise to the welding heat. Clean the scarfed surface and strike lightly at first, followed by heavier blows. The appearance of steel when at a welding heat is a pale straw color.

Always avoid a weld of high carbon steel alone, when possible.

Steel may also be welded to wrought iron. This is done in the manufacturing of edged tools. The body of the tool is of iron, to which a piece of steel is welded to form the cutting edge. This class of work is best done with a fire of anthracite coal, though coke or charcoal may be used. The fire should be burning brightly when the heating is done. Lay the iron and steel on the coal until they are red hot. Then sprinkle the surfaces of both with the flux and let it vitrify. A convenient method of doing this is to have the powdered flux (borax preferred) in a pepper pot. As soon as the heat has changed the metals to a straw color lay them together and strike. A single blow of a drop hammer, or four or five with a light sledge will do the work. Be sure that these pieces are well covered with a flux before attempting to weld.

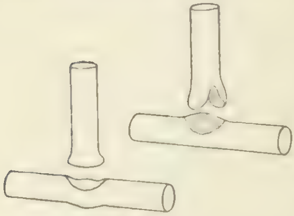


Fig. 32

CALCULATION OF STOCK FOR BENT SHAPES.

It is always convenient and frequently necessary to know the exact amount of stock required to make a given piece of work. There are four general methods used for determining this. The first and most accurate method, if it can be used conveniently, is mathematical calculation. Taking as an example the bent piece illustrated in Fig. 33. If the out-

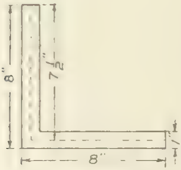


Fig. 33

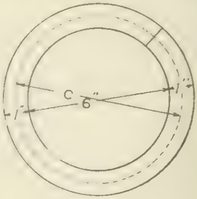


Fig. 34.

side of this be measured, it would seem as though 16 inches of stock were required. If the inside be measured, 14 inches would seem the proper amount. It has been found by experiment that if a piece of straight stock be taken and a line drawn on it through the center, and this piece of stock then be bent and the lengths of the inside, center, and outside lines be measured, the outside line will lengthen considerably as the piece is bent. The inside line will shorten correspondingly, while the center line will remain comparatively unaltered in length. This is universally true, and the proper length of stock required for making any bent shape may always be obtained by measuring the center line of the curve or bend. To return to the first example: In this case, if the center line of the stock be measured, $7\frac{1}{2}$ inches will be the length for each leg, thus making a total of 15 inches of stock required to make that particular bend. This is a universal rule which should always be followed when measuring stock, to take the length of the center line.

Circles. On circles and parts of circles the length of stock may be easily calculated. The circumference, or distance around a circle, is found by multiplying the diameter by $3\frac{1}{7}$ or, more accurately, 3. 1416. As an illustration, the stock necessary to bend up the ring in Fig. 34, would be calculated as follows: The inside diameter of the ring is six inches and the stock is one inch thick. This would make the diameter of the circle made by the center line, shown by C, which may be called the *Calculating Diameter*, seven inches, and the length of stock required would be $7 \times 3\frac{1}{7}$ or 22 inches.

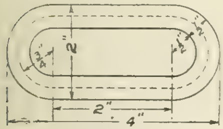


Fig. 35.

Link. A combination of circle and straight lines is illustrated in Fig. 35. This link may be divided into two semicircles at the end, with two straight pieces at the sides. The outside diameter of the ends being two inches, would leave the straight sides each two inches long. The *calculating* diameter for the ends would be $1\frac{1}{2}$ inches. The total length of stock then required for the ends would be $1\frac{1}{2} \times 3\frac{1}{7} = 4\frac{5}{7}$ or approximately $4\frac{11}{16}$ inches. As each of the straight sides will take two inches of stock, the total length required would be 4'' + 4 [illegible]'' = 8[illegible] inches. With a slight allowance for welding, the amount cut should be 8[illegible]''. Another method of measuring stock is by using a measuring wheel such as is shown in Fig. 36.

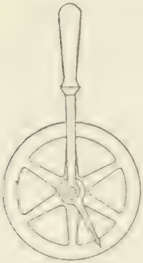


Fig. 36.

This is simply a light running wheel mounted on a handle with some sort of a pointer attached. The wheel is sometimes made with a circumference of 24 inches and the rim graduated in inches and eights. To use it, the wheel is placed lightly in contact with the line or object which it is wished to measure, with the zero mark on the wheel corresponding to the point from which the measurement is started. The wheel is then pushed along the surface following the line to be measured, with just enough pressure to cause it to revolve. By counting the revolutions and parts of a revolution made by the wheel, the required distance may be easily measured.

Scrolls and Irregular Shapes may be measured by either of two methods. The commoner way is to lay the scroll or shape off full size and measure the length by laying on this full sized drawing a string or thin piece of wire, causing the string or wire to follow the center line of the bent stock. The wire or string is then straightened and the length measured. This is about the easiest and best way of measuring work of this character. Another method which is more practical in the drafting room, consists of using a pair of dividers. The points of the dividers are set fairly close together and the center line is then stepped off and the number of steps counted. The same number of spaces are then laid off along a straight line and the length measured.

FORGING OPERATIONS.

Shaping. After the metal has been heated it is shaped with the hammer. This shaping may consist of drawing, upsetting or bending. In *drawing* a bar of iron it is made longer and of a smaller diameter. *Upsetting* consists of shortening the bar with a corresponding increase of diameter. This work is usually done with a helper using a sledge hammer; the smith using a light hand hammer.

They strike alternate blows. The helper must watch the point upon which the smith strikes and strike in the same place. Where two helpers are employed the smith strikes after each man. A blow on the anvil by the smith is a signal to stop striking.

Finishing. As the hammer usually marks the metal, it is customary to leave the metal a little full and finish by the use of flatters and swages. This applies to work that has been shaped under the sledge. Light work can be dressed smoothly, and the hammer can be made to obliterate its own marks.

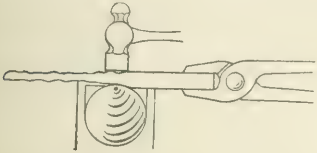


Fig. 37.

Drawing Out. In drawing out as well as in all other forging operations where heavy work is to be done, it is always best to heat the work to as high a temperature as the metal will stand without injury. Work can sometimes be drawn out much faster by working over the horn of the anvil than on the face, the reason being this: When a piece of work is hammered on the anvil face it flattens out and spreads nearly as much in width as it does in length, working it out longer and wider. As the piece is not wanted wider but merely longer, all the work spent in increasing the width of the stock is wasted. If the hammering is done over the horn of the anvil as illustrated in Fig. 37, the rounded horn acts as a blunt wedge, forcing the metal lengthwise and thus utilizes almost the entire energy of a blow in stretching the metal in the desired direction. Fullers are also used to serve the same purpose and when working under the steam hammer a round bar sometimes takes the place of the fuller or horn of the anvil.

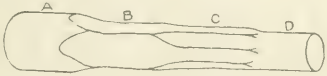


Fig. 38.

Drawing Out and Pointing Round Stock. When drawing out or pointing round stock, it should always first be forged down square to the required size and then in as few blows as possible, rounded up. Fig. 38 illustrates, in a general way, the different steps in drawing down a round bar from a large to a smaller size the first step being to hammer it down square as at B. This square shape is then made octagonal as at C and the octagon is finally rounded up as at D. If an attempt be made to hammer the bar by pounding it round and round without the preliminary squaring, the bar is very liable to split through the center, the action being a good deal as illustrated in Fig. 39, the effect of the blow coming as shown by the arrows A. The metal is squeezed together in this direction and forced apart in the direction at right angles as indicated by the arrows B. Then if the piece be slightly rolled for another blow, the sides will roll by each other, and cracks and splits will sooner or later develop, leaving the bar, if it should be sawed through the center, in a good deal the shape shown in Fig. 40. Particular care should be taken in making conical points as it is almost impossible to work stock down to a round point unless the point be first forged down to a square or pyramidal shape.

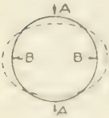


Fig. 39.

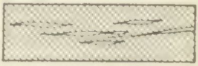


Fig. 40.

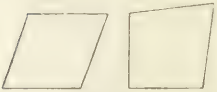


Fig. 41.

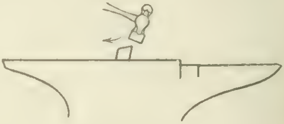


Fig. 42.

Truing Up Work. In drawing out it often happens that the bar becomes worked into an irregular or diamond shape, similar to the section shown in Fig. 41. To remedy this, and square up the bad corners, the bar should be laid across the anvil and worked much as shown in Fig. 42, the blows coming in the direction indicated by the arrow. Just as the hammer strikes the work it should be given a sort of sliding motion. No attempt should be made to square up a corner by striking squarely down upon the work. The hammering should also be done in such a way as to force the metal back into the bar and away from the high corner.

Upsetting. When a piece is worked in such a way that its length is shortened and either or both its thickness and width increased, the piece is said to be upset and the operation is known as upsetting. There are several methods of upsetting, the one used depending largely upon the shape of the work. In short pieces the work is generally stood on end on the anvil, the hammering being done directly down upon the upper end. The work should always be kept straight, and as soon as a bend or kink is started, it should be straightened out. When a long piece is to be upset it is generally swung back and forth horizontally and the upsetting done by ramming the end against the anvil. The effect of the blow has a decided influence upon the shape of the upset piece, as shown by the sketches of the two rivets in Fig. 43. Light blows affect the metal for a short distance only, as shown by the swelled out end, while the effect of heavier blows is felt more uniformly throughout the entire length.

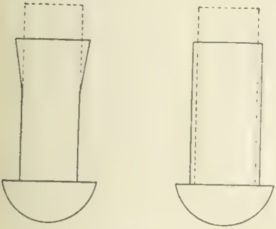


Fig. 43

When rivets are to be driven to fill holes tightly, the blows should be heavy, thus upsetting the rivet tightly into the holes. If a rivet is wanted to hold two pieces together in such a way that they may move, as for instance the rivet in a pair of tongs, the head should be formed with light blows, thus working only the end of the rivet. The part of the work which is heated to the highest temperature is the part which will be most upset, and when upsetting is wished at one point only, that point should be heated to the highest temperature, leaving the other parts of the bar as cold as possible. Upsetting long pieces is sometimes done by raising the piece and allowing it to drop on a heavy cast-iron plate set in the floor. These plates are known as upsetting plates.

Fig. 44.

Punching. Two kinds of punches are commonly used for making holes in hot metal; the straight hand punch used with a hand hammer and the one used for heavier stock, provided with a handle and used with a sledge hammer. Punches should of course be made of tool steel. For punching small holes in thin iron a hand punch is ordinarily used. This is a bar of round or octagonal steel, eight or ten inches in length, with the end forged down tapering to the same shape, but slightly smaller than the hole to be punched. Such a punch for round holes is shown in Fig. 44. The end of the punch should be perfectly square across, not at all rounding. For heavier and faster work with a helper, a punch similar to Fig. 45 is used, the striking being done with a sledge hammer.

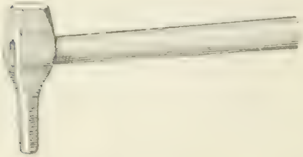


Fig. 45.

Fig. 46 illustrates the successive steps in punching a clean hole through a piece of hot iron. The work is first laid flat on the anvil and the punch driven about half way through as shown at A. This compresses the metal directly underneath the end of the punch and raises a slight bulge on the opposite side of the bar. The piece is then turned over and the punch driven into the bar from this side (the hole being located by the bulge) while the bar is lying flat on the anvil. The punch should be driven about half of the way through leaving the work as at C. The bar is then moved over the small round hole in the end of the anvil, or is placed on some object having a hole slightly larger than the hole to be punched, and the punch

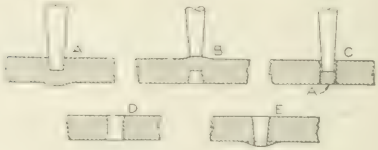


Fig. 46.

driven clear through, driving out the small piece A and leaving the hole as shown at D. It would seem easier to drive the punch completely through the work from one side. If this were done, however, the hole would be left as shown at E, one side would be rounded in, and the other side would be bulged out, while the hole would have a decided taper, being larger at the end from which the punching was done. If the piece be thick, after the hole is started, a little powdered coal is put in and the punching continued. The coal prevents the punch from sticking to some extent.

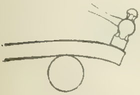


Fig. 47.

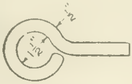


Fig. 48.

Ring and Eye Bending. In making a ring or eye the first step is of course, to calculate the amount of stock required. In making ordinary rings four or five inches in diameter, the stock should be heated for about half its length. In starting the bend, the extreme end of the piece is first bent by placing the bar across the horn of the anvil and bending it down as illustrated in Fig. 47. The bar is then pushed ahead and bent down as it is fed forward. The blows should not come directly on top of the horn but fall outside of the point of support as illustrated. This bends the iron and does not hammer it out of shape. One-half of the circle is bent in this way, the stock turned end for end, the other end heated, and the second half bent in the same way as the first, the bending being started from the end as before.

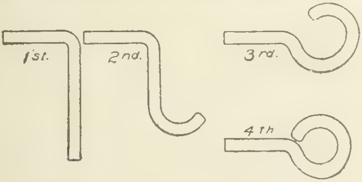


Fig. 49.

Eye bending is done in a somewhat different manner. Suppose it be required to bend up an eye as shown in Fig. 48. To calculate the amount of stock required: The diameter in this case to be used is two inches, and the amount of stock required 2″ × 3⅐″ = 6²⁄₇″, or practically 6⅜″. This distance is laid off by making a chalk mark on the anvil 6⅜″ from the end. The iron is heated and placed against the anvil with one end on the chalk mark and the other end extending over the end of the anvil. The hand hammer is then held on the bar with one edge at the edge of the anvil, thus measuring off the required distance on the bar. Still holding the hammer on the bar the piece is laid across the anvil, with the edge of the hammer even with the edge of the anvil and the 6⅜ inches extending over the edge or corner. This piece is then bent down into a right angle as shown in the first illustration of Fig. 49. The eye is bent in much the same manner as the ring, except that all the bending is done from one end, the successive steps being shown in the illustration. Small eyes are closed up in the manner shown in Fig. 50.

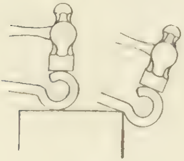


Fig. 50

Bend with Square Forged Corner. Brackets and other forgings are frequently made with the outside corner square and sharp, as shown at C, Fig. 51. This may be done in either of two ways; by the first method the corner is bent from the size of stock required for the sides, being first bent to the shape of A. This corner is then

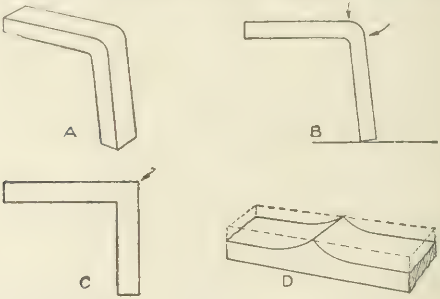
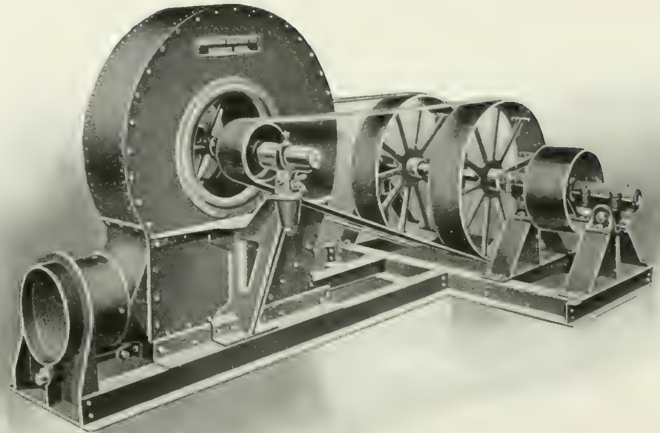


Fig. 51.



STEEL PRESSURE BLOWER.

American Blower Company

squared by upsetting the metal at the bend, the blows coming as shown by the arrows at B. The work should rest on the anvil face, and not over one corner, while being hammered.

The second method is to use thicker stock and draw out the ends leaving a hump, shown at D, where the outside corner of the bend is to come. The dotted lines show the original shape of the bar; the solid lines the shape before bending. Sometimes stock is taken of the size used in the first method and upset to form the ridge, in place of drawing out the heavier stock.

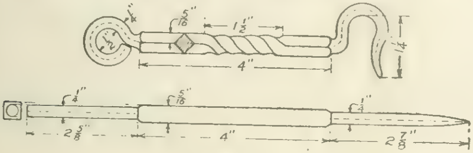


Fig. 52

The first method is the one more commonly used on medium sized work.

SIMPLE FORGING.

Twisted Gate Hook. It should be understood that the description given here will serve not only as a description of the particular piece in question but also as a general description of a variety of similarly shaped forgings. The methods used may be employed on other forgings of the same general shape.

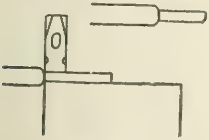


Fig. 53.

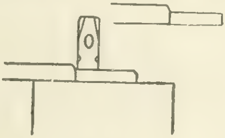


Fig. 54.

Fig. 52 shows a twisted gate hook. To start with, it is necessary to determine exactly what lengths the different parts of the hook will have after they are forged to dimensions, and before they are bent to shape. Before bending, the work is first drawn down to size as is indicated. The bar is left square in the center for the central part, and each end is drawn to one-quarter inch round to form the hook and eye ends. The length of stock after being drawn out to ¼″ round required to make the eye, is 2⅜ inches. Allowing about one-quarter of an inch for the straight part before the eye is reached would make the total amount of stock required for the eye 2⅝ inches. To obtain the amount of stock for the hook it is necessary to lay off the hook full size. If the drawing be full sized the measuring may be done directly on the drawing, but if not, a rough sketch having the proper dimensions should be laid off and the measuring done on that, the measuring of course being done along the dotted center line. This measuring is done by simply laying a string on the dotted line, then straightening out the string and measuring its length. In this way it will be found that 2⅜ inches is required by the hook. The first step is then to forge the work into the shape shown in Fig. 52.

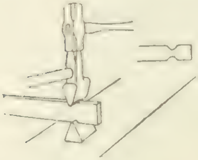


Fig. 55.

Forming Shoulders. The shoulder where the round stock joins the square should be forged in the manner indicated in Fig. 53. The bar is laid across the anvil with the point where the shoulder is wished, lying directly on the corner of the anvil. The set hammer is then placed on top of the work in such a way that the edge of the set hammer comes directly in line with the edge of the anvil. The set hammer is then driven into the work with a sledge hammer. The bar should be turned continually or an uneven shoulder will be the result. If a shoulder is wanted on one side only, as illustrated in Fig. 54, it should be worked in as indicated there. That is, one side of the iron should lie flat on the anvil face while the set hammer works down the metal next to the shoulder.

After the two ends of the hook are drawn out, the eye and the hook are bent up into shape. The twist in the center of the hook may be made by using either two pairs of tongs or twisting in a vise. By the latter method a mark is first made on the vise in such a way that when the end of the hook is placed even with the mark, the edge of the vise will come at the end of the point where the twist is wanted.

The hook should be heated and placed in the vise, the other end being grasped by a pair of tongs in such a way that the distance between the tongs and the vise is just equal in length to the twist. The twist is made by simply revolving the tongs around. In making a twist of this kind, no allowance need be made in length, as it practically has no effect on the length of the stock.

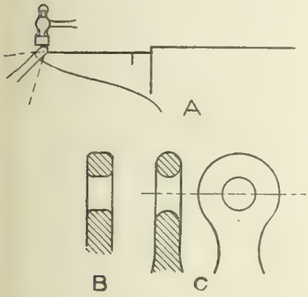


Fig. 56.

Eye Bolts are made by two general methods, being either solid or welded. The solid eye bolt is much the stronger. A solid eye bolt, or forged eye, as it is sometimes called, may be started in the general manner illustrated in Fig. 55. A nick is made on either side of a flat bar by using top and bottom fullers as illustrated. The end is then rounded up as shown in Fig. 56. Particular attention should be given to seeing that the eye is forged as nearly to a perfect circle as possible before any punching is done. The stock around the eye is rounded up over the horn of the anvil, by swinging it back and forth as it is hammered. The hole when first punched is like B, but when finished should be like C. The other end of the bar is then drawn down to form the round shank. If a very long shank is wanted a short stub shank may be formed and a round bar of the proper size welded on.

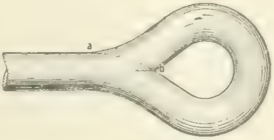


Fig. 57.

Welded eye bolts may be made in two different ways. The easier method produces an eye shaped as in Fig. 57. To make such a bolt first scarf the end so that it will fit over the bend of the rod along the dotted line *a b*. Bend the eye over the horn of the anvil. Finally bring to a welding heat and weld in accordance with instructions already given.

An eye of better appearance, as shown in Fig. 58, is made as follows: Upset the body of the metal as a seat for the scarf at the end, shown at *a*, Fig. 58. Scarf the end of the bar and bend over the horn of the anvil into a true circle to fit the seat at *a*, and then weld as before.

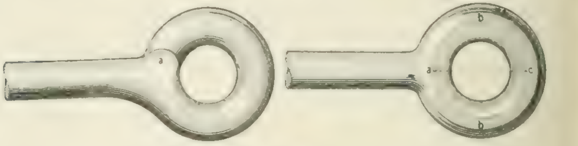


Fig. 58.

The length of metal required for an eye or ring is nearly equal to the length of the circumference of a circle whose diameter is equal to the mean diameter of the ring. Thus in Fig. 58 the length required for the eye will be approximately the length of the circle *a b c b* whose diameter is *a c*.

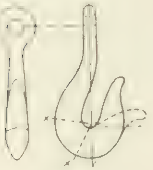


Fig. 59.

Chain Hooks. These are made in a variety of shapes and with solid or welded eyes, the general method of making the eyes being exactly as described before under "Eye Bolts". A common shape is shown in Fig. 59. The stock is forged into shape similar to Fig. 60 before being bent. To determine the length A the drawing is measured in the same way as described in making the gate hook. The weakest point in most hooks is the part lying between the lines marked *x x* in Fig. 59. This part of the hook should be heavier and stronger than the other parts. When a strain is put on the hook, there is always a tendency to straighten out or to assume the shape shown by the dotted lines. When forging the hook into shape, the dimension B, Fig. 60, should be made such that the heaviest part of the hook comes in this weakest point. After the hook is entirely forged to size, it should be bent into shape. Hooks

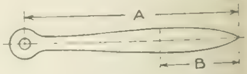


Fig. 60.

are also made from round and square iron. When made for hooking over a link, and so shaped that the throat or opening is just large enough to slip easily over a link edgewise, but too narrow to slip off of this link down to the one which, of course, is turned at right angles, the hook is known as a grab hook.

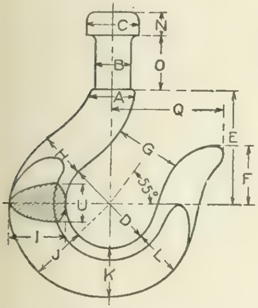


Fig. 61.

Hoisting Hooks. A widely accepted shape for hooks of this character used on cranes is shown on Fig. 61. The shape and formulae for the dimensions are given by Mr. Henry R. Town in his "Treatise on Cranes". T = Working load in tons of 2,000 lbs. A = Diameter of round stock, in inches, used to form the hook. The size of stock required for a hook to carry any particular load is given below. The load for which the hook is designed is given in the upper line, the lower line gives the size of the stock to be used in making the hook.

T =	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	3	4	5	6	8	10
A =	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$1\frac{1}{16}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{7}{8}$	$3\frac{1}{4}$

The other dimensions of the hook are found by the following formulae, all of the dimensions being given in inches.

D = .5 T + 1.25 I = 1.33 A
E = .64 T + 1.6 J = 1.2 A
F = .33 T + .85 K = 1.13 A
G = .75 D L = 1.05 A
O = .363T + .66 C = 1.25 A
Q = .64 T + 1.6 N = .85 B − .16
H = 1.08 A, B = .875 A U = .866A

To illustrate the use of the table, suppose it be required to make a hook to raise a load of 500 lbs. or one-quarter of a ton. In the line marked "T" is found the load $\frac{1}{4}$. Directly below are figures

$\frac{11}{16}$ showing the size of stock to be used. The dimensions of the hook will be found as follows:

D = .5 × ¼ + 1.25″ = 1⅜″.
E = .64 × ¼ + 1.6″ = 1¾″ about. Etc.

I = 1.33 A = 1.33 × $\frac{11}{16}$ = .915 or about $\frac{29}{32}$″.

When reducing the decimals the dimensions which have to do only with the bending of the hook, *i.e.*, the opening, length, the length of point, etc., may be taken to the nearest 16th, but the dimensions through the body of the hook or stock should be reduced to the nearest 32nd on small hooks. The completed dimensions of the hook in question, 500 lbs. capacity, would be as follows:

D = 1⅜″
E = 1¾″
F = 1[illegible]″
G = 1″
O = ¼″
Q = 1¼″
H = [illegible]″

I = $\frac{29}{32}$″
J = $\frac{13}{16}$″
K = $\frac{25}{32}$″
L = $\frac{23}{32}$″
M = $\frac{11}{32}$″
U = $\frac{9}{16}$″

Bolts. Bolts are made by two methods, the head being made by either upsetting or welding. The first method is more common on small bolts and machine made bolts. The welded head is more commonly used for heavy, hand forged bolts. The upset head is the stronger provided both are equally well made. The size of the bolt is always given as the diameter and length of shank or stem. Thus a bolt known as ½″ × 6″, or ½″ bolt 6″ long, would mean a bolt having a shank ½″ in diameter and 6″ long from the under side of the head to the end of the stem, having the dimensions of the bolt shown in Fig. 62. The dimensions of the bolt heads are always the same for the same sized bolt, and are determined from the diameter of the shank. The diameter of the head, shown at D, Fig. 62, is the distance across the head from flat side to flat side, and is known as the diameter *across the flats.*

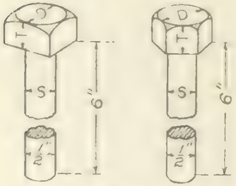


Fig. 62.

The thickness of the head is taken, as shown at T. If S equals the diameter of the shank of the bolt, the dimensions of the head would be as follows:

$$D = 1\tfrac{1}{2} \times S + \tfrac{1}{8}''$$
$$T = S$$

For a two-inch bolt the dimensions would be as follows:

Diameter of head $1\tfrac{1}{2} \times 2'' + \tfrac{1}{8}'' = 3\tfrac{1}{8}''$

The thickness of head would be equal to diameter of the shank, or 2″. These dimensions are for rough or unfinished heads. Each dimension of a finished head is $\frac{1}{16}$ of an inch less than the same dimension of a rough head. Bolts generally have the top corners of the head rounded or chamfered off. This may be done with a hand hammer; or a cupping tool, which is simply a set hammer with the bottom face hollowed out into a cup shape, may be used.

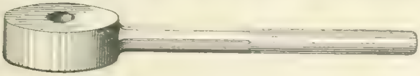


Fig. 63.

Upset Head Bolts. The general method of making bolts of this kind, when a single bolt is wanted, is described below. The method of upsetting is shown in Fig. 64.

Where large quantities of bolts are to be made, the bars are heated in a furnace and headed by special machinery. Where the work is done by hand the tools are of the simplest character. The header consists of a disc in which a hole has been drilled to correspond to the diameter of the bolt. A handle 12 or 15 inches in length is welded to the disc. Such a tool is shown in Fig. 63. The hole should be about $\frac{1}{32}$ inch larger than the nominal size of iron. To make a bolt with this tool: First cut off the iron to the required length; then heat the end to be headed, to a dull straw color; strike the end with a hammer or against the anvil and upset it so that the portion intended for the formation of the head will not pass through the header. Then place the hole of the header over the square hole in the tail of the

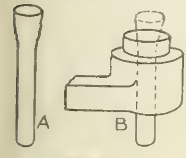


Fig. 64.

anvil and drop the cold end of the bolt through it. Strike the projecting portion of the bar and upset it until the requisite thickness of head is obtained This will probably leave a head of curved but irregular outline. Remove from the header and square the head thus upset, on the face of the anvil. This will probably thicken the head. Again drop the cold end through the header and strike the head until it is reduced to proper thickness. After which, again square the edges on the face of the anvil. In doing this work, the smith will hold the header in his left hand. The work will be facilitated if a helper assists with a sledge hammer.

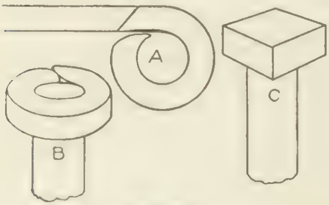


Fig. 65.

There are a number of simple tools in use for clamping the bar while it is being headed so as to avoid the preliminary upsetting.

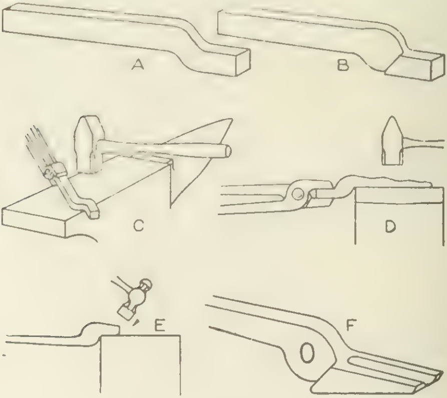


Fig. 66.

Welded Head Bolts are made by welding a ring of square iron around the end of the shank to form the head. The ring is generally bent up on the end of a bar as shown at A, Fig. 65, but not welded. This ring is cut off and placed on the end of the shank as shown at B. The joint in the ring should be left slightly open to allow for the expansion in welding. The ring is fastened to the end of the shank by striking it on one side and squeezing it against the shank. The bolt is put into the fire, heated to the welding heat, and the head welded up into the required shape. The ring should not be welded round at first, as it is difficult in this way to make a sound joint, there being a much better chance of doing sound work by welding the head directly square or hexagonal as required. No attention need be paid to the joint in the ring as this will take care of itself. Considerable care must be used in taking the welding heat, as all the heat which reaches the joint must pass through the ring and there is a good chance of burning the ring before the shank reaches the welding heat if the heating is not done slowly and carefully.

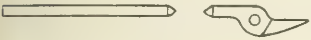


Fig. 67.

Tongs. Common flat jawed tongs, such as are used for holding light work up to about three-quarters of an inch thick, may be made as follows: Stock should be about three-quarters of an inch square. The first step is to make a bend near the end similar to A in Fig. 66. The bent stock is then laid across the anvil in the position shown at C and the eye formed by striking down upon it with a sledge hammer. A set hammer may be used for this work by placing the work flat side down on the top of the anvil and working down the stock for the eye, next to the shoulder, with the set hammer. To make the handle, enough stock may be taken and drawn out as shown at D and a complete handle forged in this way, or a small amount of stock may be taken and a short stub forged out. Enough round stock is then welded on to make the proper length

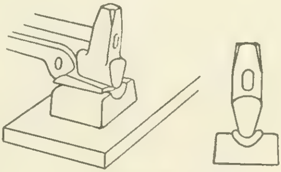


Fig. 68.

of handle, as shown in Fig. 67. The jaw is tapered down as shown at E. The last step is to punch the hole for the rivet. It is always a good plan to slightly crease the inside face of the jaw with a fuller, as this insures the jaws gripping the work firmly with the edges, and not touching it simply at one point in the center, as they sometimes do if this crease is not made. The tongs are then riveted together, the riveting being done with the round end of the hammer; in this way a head is formed on the rivet without upsetting the shank of the rivet very much where it passes through the hole. After riveting, the tongs will probably be stiff or hard to move. They may be loosened up by heating the eye part red hot and moving the handles forward and backward two or three times. They should then be firmly fitted to the work to be handled.

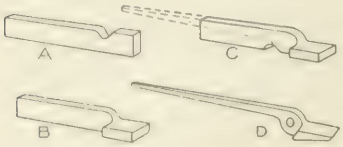


Fig. 69.

Tongs for Round Stock may be made by the general method described above, the only difference being that after the jaws are shaped, and before riveting together, they should be rounded up as illustrated in Fig. 68, using a fuller and swage as shown.

Light Tongs may be made from flat stock in the manner illustrated in Fig. 69. A cut is made in a piece of flat stock, with a fuller, near one end. This end is twisted over at right angles as shown at B. Another cut is made on the opposite side, as at C, and the end drawn out as indicated by the dotted lines. The tongs are then finished in the usual way. Tongs of this character may be used for very light work and are easily made.

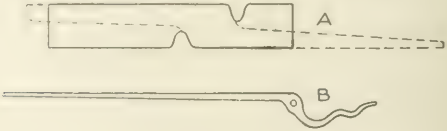


Fig. 70.

Pick-Up Tongs are made in much the same way as described above, the different steps being illustrated in Fig. 70.

Bolt Tongs may be made from round stock, although square may be sometimes used to advantage. The first step is to bend the bar in the shape shown in Fig. 71. This may be done by the fuller at the edge of the anvil, shown at A, or on a swage block as at B. The jaw proper is rounded and finished with a fuller and swage as shown in Fig. 72. The part between the jaw proper and the eye may be worked down into shape by the fuller and set hammer. The finishing may be done as indicated in Fig. 73. The eye and handle are then flattened down and drawn out, the tongs are punched, riveted together, finished, and fitted in the usual manner.

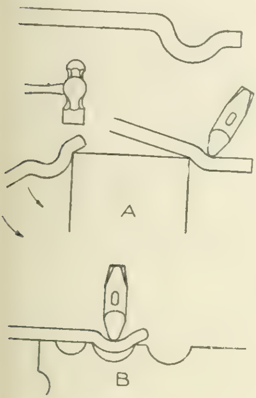


Fig. 71

Ladles similar to the one shown in Fig. 74, may be made from two pieces welded together, one forming the handle, the other the bowl, or as sometimes is done, the handle may be riveted on. A piece of flat stock is first "laid out" as shown in Fig. 75. This is then cut out with a cold chisel and the handle welded on at the projecting point. The bowl is formed by heating the stock to an even heat and placing it over a round hole in a swage block or other object

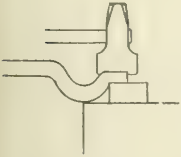


Fig. 72.

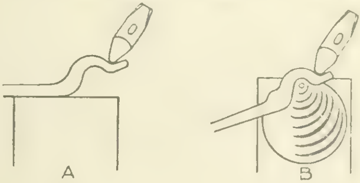


Fig. 73.

This hole should be slightly smaller than the outside diameter of the piece to be worked. To round the bowl it is worked as indicated in Fig. 76, with the pene end of the hammer. The forming should be done as much as possible by working near the edge of the piece rather than in the center. After the bowl has been properly shaped the edges should be ground off smooth and the lips formed as shown in Fig. 77. This is done by placing the part from which the lip is made against one of the small grooves in the side of the swage block and driving in a piece of small round iron, thus hollowing out the lip. The stock draws in somewhat when being rounded up. For the bowl of a ladle 3½″ in diameter, the stock when flat should have an outside diameter of about four inches, and be one-eighth of an inch thick. Machine steel should be used for making the bowl. If ordinary wrought iron is used the metal is almost sure to split.

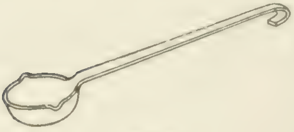


Fig. 74

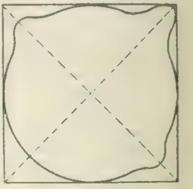


Fig. 75.

CALCULATION OF STOCK FOR FORGED WORK.

The calculations made previously for stock, were for stock which was simply bent into shape, the original section or size of the stock remaining unaltered. There is a large variety of work where the shape of the stock is considerably changed, and where it is essential to know the amount required to make a given forging. In doing this kind of work one rule must be remembered, *i.e.*, that the volume of the stock remains unaltered although its shape may be changed. Take as an example the forging shown in Fig. 78, let us determine the amount of stock required to make the piece.

The forging is made in the general manner shown in Fig. 79. A piece of stock should be taken large enough in section to make the block B, which will mean that it will be one inch wide and half an inch thick. The metal is worked by making the fuller cuts as shown in Fig. 79 and then drawing down the ends to the required size, it being, of course, necessary to know the amount of stock required for each end.

For convenience in calculating, the forging will be divided into three parts, the rounded end A, the central rectangular block B, and the square end C. The stock used being 1″ × ½″ the block B will of course require just two inches of stock. The end C would have a volume of $\frac{1}{2}'' \times \frac{1}{2}'' \times 3'' = \frac{3}{4}$ of a cubic inch. The stock has a volume of, $\frac{1}{2}'' \times 1'' \times 1''$, $= \frac{1}{2}$ of a cubic inch for each inch of length. The number of inches of stock required for the end C would then be $\frac{3}{4} \div \frac{1}{2}$ or $1\frac{1}{2}$ inches. The end A is a round shaft or cylinder four inches long and ½″ in diameter. To find the volume of a cylinder, multiply the square of the radius (½ the diameter) by $3\frac{1}{7}$ and then multiply this result by the length of the cylinder. This will give the volume of A as $\frac{1}{4} \times \frac{1}{4} \times 3\frac{1}{7} \times 4 = \frac{11}{14}$ and the amount of stock required to make this piece would be $\frac{11}{14} \div \frac{1}{2} = 1\frac{4}{7}$, which may be taken as $1\frac{5}{8}$ inches. There is, of course, some slight loss due to scaling in working the

Fig. 76.

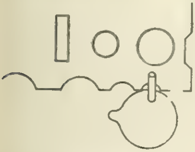


Fig. 77.

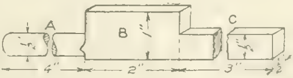


Fig. 78.

iron, which must be allowed for. This is generally done by adding a slight amount to the minimum amount required in each case. The amount of stock required in this case would be about,

Round Shaft A	$1\frac{3}{4}''$
Block B	$2''$
Square shaft C	$1\frac{5}{8}''$
Total	$5\frac{3}{8}''$

When the forging is started, cuts, which are afterward opened up with a fuller, may be made as shown by the upper sketch in Fig. 79.

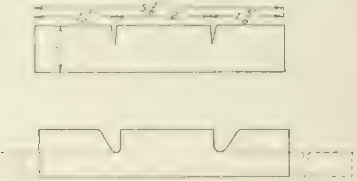


Fig. 79

In this particular case it is not absolutely necessary that exactly the proper amount of stock be taken, as it would be a very easy matter to take a little too much and trim off the surplus from the ends, after the forging was made.

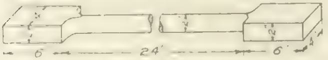


Fig. 80.

With the forging such as shown in Fig. 80, however, it is essential that the exact amount be used. This forging, which is the general shape of a connecting rod, would be started as shown in Fig. 81, and it is quite important that the distance A be correct. The stock used should be 2″ × 4″. Each end will, of course, require just 6″ of stock. The center part is a cylinder 2″ in diameter and 24″ long, the volume of which would be $1'' \times 1'' \times 3\frac{1}{7} \times 24'' = 75\frac{3}{7}$ cubic inches, which may be taken as $75\frac{1}{2}$ cubic inches. For each inch in length the 2″ × 4″ stock would

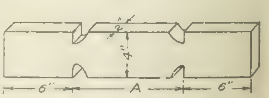


Fig. 81.

have a volume of 4″ × 2″ × 1″ = 8 cubic inches. Therefore it would require 75½ ÷ 8 = 9 $\frac{7}{16}$″ of stock, to form the central piece, consequently the distance between the cuts shown at A in Fig. 81 will be 9 $\frac{7}{16}$″. To this might be added a slight allowance for loss in scaling. The total amount of stock required would be 6″ + 6″ + 9 $\frac{7}{16}$″ = 21 $\frac{7}{16}$″. Any forging may generally be separated into simple parts of uniform shape as was done above. In this form the calculation may be easily made.

Weight of Forging. To find the weight of any forging the volume may first be found in cubic inches and this multiplied by .2779, the weight of wrought iron per cubic inch. If the forging be made of steel, the figures .2936 should be used in place of .2779. This gives the weight in pounds. Below is given the weight of wrought iron, cast iron and steel both in pounds per cubic inch and per cubic foot.

Cast Iron	450 per cu. ft.	.2604 per cu. inch.
Wrought Iron	480 " " "	.2779 " " "
Steel	490 " " "	.2936 " " "

Suppose it were required to find the weight of the forging shown in Fig. 78. A has a volume of $\frac{15}{16}$ cubic inch, C $\frac{3}{4}$ cubic inch and B 1 cubic inch, making a total of 2 $\frac{11}{16}$ cubic inches. If the forging were made of wrought iron it would weigh 2 $\frac{11}{16}$ × .2779 = .7 lbs. The forging in Fig. 80 has a total volume of 171 $\frac{1}{2}$ cubic inches and would weigh, if made of wrought iron, 47.64 lbs.

A much easier way to calculate weights is to use tables such as given on pages 46 and 47. The first table gives the weights *per foot* of flat iron bars. In the second table is given the weights for each foot of length of round and square bars.

When using the table on page 46 to ascertain the weight of any size of flat iron per foot of length, look in the first column at the left for the thickness. Then follow out in a horizontal line to the column giving the width. The number given will be the weight in pounds of one foot of the desired size.

To use the table for calculating weights, the procedure would be as follows:

Taking Fig. 80 as an example, each end is 2″ × 4″ and 6″ long and the two ends would be equal, as far as weight is concerned, to a bar

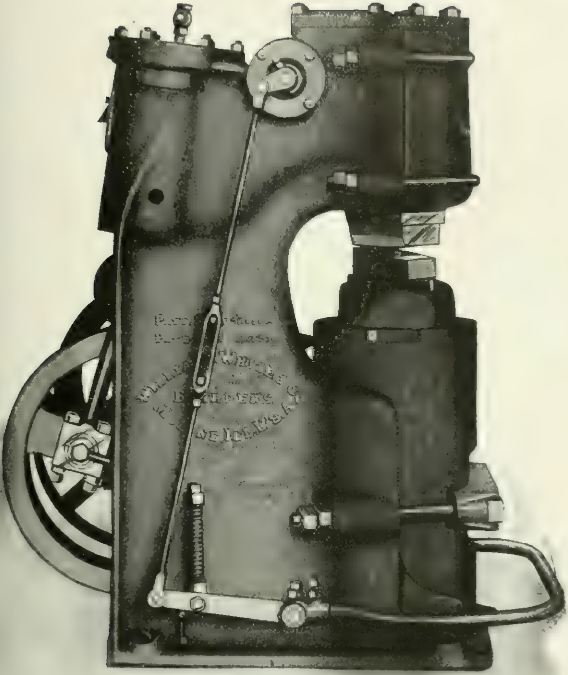
WEIGHT OF FLAT ROLLED IRON.

Length, 12 inches.

Thickness.	WIDTHS.																				
	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞	3
⅛	.208	.260	.313	.365	.417	.469	.521	.573	.625	.677	.729	.781	.833	.885	.938	.989	1.04	1.09	1.15	1.20	1.25
¼	.417	.521	.625	.729	.833	.938	1.04	1.15	1.25	1.35	1.46	1.56	1.67	1.77	1.88	1.98	2.08	2.18	2.29	2.39	2.50
⅜	.625	.781	.938	1.09	1.25	1.41	1.56	1.72	1.88	2.03	2.19	2.35	2.50	2.65	2.81	2.97	3.13	3.28	3.44	3.59	3.75
½	.833	1.04	1.25	1.46	1.67	1.88	2.08	2.29	2.50	2.71	2.92	3.13	3.33	3.54	3.75	3.96	4.17	4.37	4.58	4.79	5.00
⅝		1.30	1.56	1.82	2.08	2.34	2.60	2.86	3.13	3.39	3.65	3.91	4.17	4.43	4.69	4.95	5.21	5.47	5.73	5.99	6.25
¾			1.88	2.19	2.50	2.81	3.13	3.44	3.75	4.06	4.38	4.69	5.00	5.31	5.63	5.94	6.25	6.56	6.88	7.19	7.50
⅞				2.55	2.92	3.28	3.65	4.01	4.38	4.74	5.10	5.46	5.83	6.19	6.57	6.92	7.29	7.65	8.02	8.38	8.75
1					3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67	7.08	7.50	7.91	8.33	8.75	9.17	9.58	10.00
1⅛						4.22	4.69	5.15	5.63	6.09	6.56	7.03	7.50	7.97	8.44	8.90	9.38	9.84	10.31	10.78	11.25
1¼							5.21	5.73	6.25	6.77	7.29	7.81	8.33	8.85	9.38	9.89	10.42	10.94	11.46	11.98	12.50
1⅜								6.30	6.88	7.45	8.02	8.59	9.17	9.74	10.32	10.88	11.46	12.03	12.60	13.18	13.75
1½									7.50	8.13	8.75	9.37	10.00	10.62	11.25	11.87	12.50	13.12	13.75	14.37	15.00
1⅝										8.80	9.45	10.11	10.83	11.51	12.19	12.86	13.54	14.22	14.90	15.57	16.25
1¾											10.21	10.94	11.67	12.40	13.13	13.85	14.58	15.31	16.04	16.77	17.50
1⅞												11.72	12.50	13.28	14.06	14.84	15.63	16.41	17.19	17.97	18.75
2													13.33	14.16	15.00	15.83	16.67	17.50	18.33	19.16	20.00
2⅛														15.05	15.94	16.81	17.71	18.59	19.48	20.36	21.25
2¼															16.88	17.80	18.75	19.69	20.63	21.56	22.50
2⅜																18.80	19.79	20.78	21.78	22.76	23.75
2½																	20.83	21.87	22.93	23.96	25.00
2⅝																		22.97	24.07	25.16	26.25
2¾																			25.21	26.35	27.50
2⅞																				27.55	28.75
3																					30.00

2" × 4" and 1 ft. long. From the table it will be seen that a bar 2" × 2" weighs 13.33 lbs. and a bar 2" × 4", being twice as thick would weigh twice that, or 26.66 lbs. A bar two inches in diameter weighs 10.47 lbs. per foot and as the central part of the forging is 2 ft. long, it will weigh 20.94 lbs., making the total weight of the forging 47.6 lbs.

Finish. Many forgings are machined or "finished" after leaving the forge shop. The drawings are always made to represent the finished work and therefore give the finished dimensions, and it is necessary when this finishing is to be done, to make allowance for it when making the forging, that all parts which have to be *finished* or "machined" may be left with extra metal to be removed in finishing. The parts required to be finished are generally marked on the drawing. Sometimes the finished surfaces have the word "finished" marked on them. Sometimes the finishing is shown simply by the symbol f, as used in Fig. 82, showing that the shafts and pin only of the crank are to be finished. When all surfaces of a piece are to be finished the words *finish all over* are sometimes marked on the drawing.



80-POUND HAMMER WITH DETACHED ANVIL.

Williams, White and Co.

WEIGHTS OF ROUND AND SQUARE ROLLED IRON.
Length, 12 Inches.

Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.	Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.	Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.
0			2 11/16	24.08	18.91	5 3/8	96.30	75.64
1/16	.013	.010	3/4	25.21	19.80	7/16	98.55	77.40
1/8	.052	.041	13/16	26.37	20.71	1/2	100.8	79.19
3/16	.117	.092	7/8	27.55	21.64	9/16	103.1	81.00
1/4	.208	.164	15/16	28.76	22.59	5/8	105.5	82.83
5/16	.326	.256	3	30.00	23.56	11/16	107.8	84.69
3/8	.469	.368	1/16	31.26	24.55	3/4	110.2	86.56
7/16	.638	.501	1/8	32.55	25.57	13/16	112.6	88.45
1/2	.833	.654	3/16	33.87	26.60	7/8	115.1	90.36
9/16	1.055	.828	1/4	35.21	27.65	15/16	117.6	92.29
5/8	1.302	1.023	5/16	36.58	28.73	6	120.0	94.25
11/16	1.576	1.237	3/8	37.97	29.82	1/8	125.1	98.22
3/4	1.875	1.473	7/16	39.39	30.94	1/4	130.2	102.3
13/16	2.201	1.728	1/2	40.83	32.07	3/8	135.5	106.4
7/8	2.552	2.004	9/16	42.30	33.23	1/2	140.8	110.6
15/16	2.930	2.301	5/8	43.80	34.40	5/8	146.3	114.9
1	3.333	2.618	11/16	45.33	35.60	3/4	151.9	119.3
1/16	3.763	2.955	3/4	46.88	36.82	7/8	157.6	123.7
1/8	4.219	3.313	13/16	48.45	38.05	7	163.3	128.3
3/16	4.701	3.692	7/8	50.05	39.31	1/8	169.2	132.9
1/4	5.208	4.091	15/16	51.68	40.59	1/4	175.2	137.6
5/16	5.742	4.510	4	53.33	41.89	3/8	181.3	142.4
3/8	6.302	4.950	1/16	55.01	43.21	1/2	187.5	147.3
7/16	6.888	5.410	1/8	56.72	44.55	5/8	193.8	152.2
1/2	7.500	5.890	3/16	58.45	45.91	3/4	200.2	157.2
9/16	8.138	6.392	1/4	60.21	47.29	7/8	206.7	162.4
5/8	8.802	6.913	5/16	61.99	48.69	8	213.3	167.6
11/16	9.492	7.455	3/8	63.80	50.11	1/4	226.9	178.2
3/4	10.21	8.018	7/16	65.64	51.55	1/2	240.8	189.2
13/16	10.95	8.601	1/2	67.50	53.01	3/4	255.2	200.4
7/8	11.72	9.204	9/16	69.39	54.50	9	270.0	212.1
15/16	12.51	9.828	5/8	71.30	56.00	1/4	285.2	224.0
2	13.33	10.47	11/16	73.24	57.52	1/2	300.8	236.3
1/16	14.18	11.14	3/4	75.21	59.07	3/4	316.9	248.9
1/8	15.05	11.82	13/16	77.20	60.63	10	333.3	261.8
3/16	15.95	12.53	7/8	79.22	62.22	1/4	350.2	275.1
1/4	16.88	13.25	15/16	81.26	63.82	1/2	367.5	288.6
5/16	17.83	14.00	5	83.33	65.45	3/4	385.2	302.5
3/8	18.80	14.77	1/16	85.43	67.10	11	403.3	316.8
7/16	19.80	15.55	1/8	87.55	68.76	1/4	421.9	331.3
1/2	20.83	16.36	3/16	89.70	70.45	1/2	440.8	346.2
9/16	21.89	17.19	1/4	91.88	72.16	3/4	460.2	361.4
5/8	22.97	18.04	5/16	94.08	73.89	12	480.	377.

The allowance for finishing on small forgings is generally about $\frac{1}{16}$" on each surface. Thus, if a block were wanted to finish 4" × 2" × 1" and $\frac{1}{16}$" were allowed for finishing, the dimensions of the forging would be $4\frac{1}{8}$" × $2\frac{1}{8}$" × $1\frac{1}{8}$". On a forging like Fig. 80, about $\frac{1}{8}$" allowance would be made for finishing, if it were called for. Thus the diameter of the central shaft would be $2\frac{1}{4}$", the thickness of the ends $2\frac{1}{4}$", etc. On larger work $\frac{1}{4}$" is sometimes allowed for machining. The amount of finish allowed depends to a large extent on the way the forging is to be finished. When hand finishing is done, that is, filing or scraping, $\frac{1}{32}$" or even $\frac{1}{64}$" is enough; when all of the finishing is done in a lathe or other machine, more material should be left.

When a forging calls for *finish*, in calculating the amount of stock, or weight, the dimensions taken should not be the actual ones

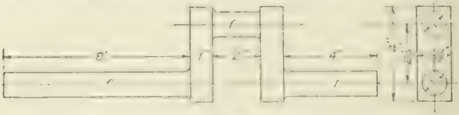


Fig. 82.

shown by the drawing, but these dimensions with the proper allowance made for *finish*.

Crank Shafts. There are several methods of forging crank shafts. The more commonly used is the commercial method, as described in detail below. When forgings were mostly made of wrought iron, the

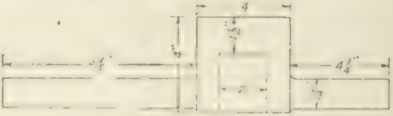


Fig. 83.

cranks were welded up of severel pieces. One piece was used for each of the shafts, one piece for each cheek or side, and another piece for the crank pin. Cranks are sometimes bent up out of round stock, but this method is only used on small work. The common method now employed where machine steel is used, is to forge the crank from one solid piece of material. The stock is taken large enough to shape

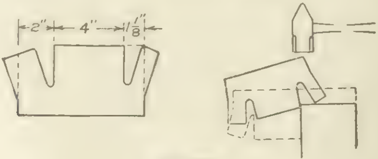


Fig. 84.

the largest part of the crank without any upsetting. If a crank be required similar to Fig. 82, the size of stock to be used should be 1½" by 4" in section.

When the forging leaves the shop, it will be left in a shape similar to the shape shown by the solid lines in Fig. 83, the dimensions shown here allowing for the necessary finishing. The crank itself would be left in a solid block, the throat being afterwards cut out as indicated by the dotted lines. A line of holes is first drilled as shown, and the block of metal to be taken out is removed by making two slits with a cold saw and the block then knocked out with a sledge hammer. It is possible to form this throat by chopping out the surplus metal with a hot chisel in the forge shop, but on small cranks in particular, such as here shown, it is generally cheaper in a well equipped shop to use the first method.

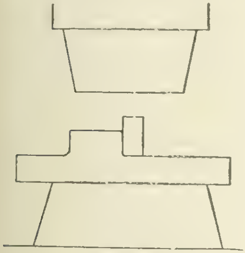


Fig. 85.

The first step is of course to calculate the amount of stock required. The long end would contain 10.13 cubic inches. As each inch of stock contains 6 cubic inches, it would require 1.7″ of stock to form this end provided there was no waste from scale. Waste does take place, however, and must be allowed for, so about 2″ of stock should be taken. The short end contains 5.22 cubic inches and would require .87″ of stock, without allowance for scale. About 1⅛″ should be taken. The total stock then required would be 7⅛″.

The first step is to make the cuts, and spread the ends as shown in Fig. 84. These ends may then be forged down with a sledge hammer as illustrated or may be worked out under the steam hammer, the finishing up against the shoulders being done as illustrated in Fig. 85. The shaft may be rounded down and finished between swages. Care must be taken to see that the cuts are properly spread before drawing out the ends. If the cuts are left without spreading, the metal will act somewhat after the manner shown in Fig. 86. The top part of the bar, as it is

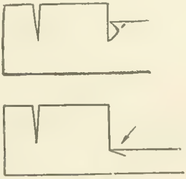


Fig. 86.

worked down, will fold over and leave a crack or *cold shut* as illustrated. When the metal starts to act in this way the fault should be corrected by trimming off the overlapping corner along the dotted line shown in the upper sketch.

Multiple-Throw Cranks. When a crank shaft has more than one crank or crank pin, it is spoken of as a multiple-throw crank. A double-throw crank is a crank shaft with two cranks. A three throw or triple throw, one with three cranks, etc. As a general rule multiple-throw cranks are forged flat, *i.e.*, the cranks are all forged in line with each other. The shafts and pins are then rough turned and the cranks are heated and twisted into shape. The forging for the double-throw crank shown in Fig. 87 would first be made in the general shape shown in Fig. 88. The parts shown by the dotted lines would then be cut out with a drill and saw as described above, and the shafts and pins rough turned, *i.e.*, turned round, but left as large as possible. The forging is then returned to the forge shop where it is heated and the cranks twisted to the desired angle. When twisting, the crank would be gripped just to the right of the point marked A. This may be done with a vise, or wrench if the crank is small, or

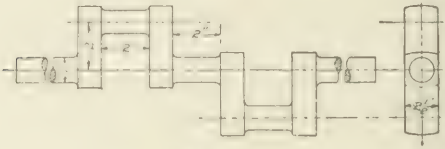


Fig. 87.

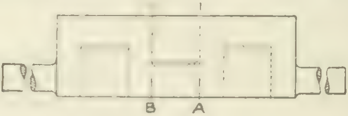


Fig. 88.

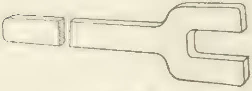


Fig. 89.

it may be held under the steam hammer. The twisting may be done with a wrench similar to Fig. 89 which may be easily made by bending up a U of flat stock and welding on a handle.

A Three-Throw Crank without any intermediate bearings is shown in Fig. 90. The rough forging for this is shown in Fig. 91. The extra metal is removed as indicated by the dotted lines and the twisting done as described before.

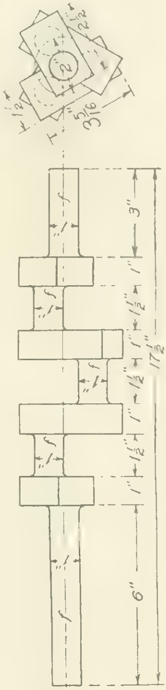


Fig. 90

Weldless Rings. Rings and eyes forged solid without any welds may be made in the general manner described below. As an example, suppose it be required to make a ring such as illustrated in Fig. 92. A flat bar is first forged rounding on the ends, punched and split as shown, this split is opened out and the ring hammered into shape. It is necessary, of course, to calculate the amount of stock required. This may be done as follows: The first step is to determine the area of the ring, which is done by taking the area of the outside circle, and subtracting from it the area of the inside circle.

Area of outside circle	12.57	sq. in.
" " inside "	7.07	" "
" " ring	5.50	" "

The stock used when making small thin rings should be twice

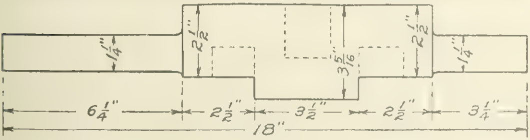


Fig. 91.

the width of the side of the ring to which is added at least one-quarter of an inch. When the bar is split the stock is more or less deformed and when worked back into shape is slightly thinned. Although no stock is lost by the hammering, an allowance must be made for the thinning and stretching and it is necessary to make the stock slightly wider on this account, as noted above. Allowing $\frac{1}{2}''$ for hammering, and taking stock $1\frac{1}{2}''$ wide, the amount of stock required would be $5.5 \div 1.5$, equal to 3.66″. Allowing a small amount for loss by scale, etc., $3\frac{11}{16}''$ of stock should be taken. In making this calculation, the thickness of the stock is not taken into consideration, as the thickness of the finished ring is the same as the stock. This general method is used on a large variety of work, particularly where rings are to be made of tool steel and should be made without a weld.

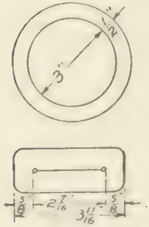


Fig 92

Another method of making weldless rings, under the steam hammer, is illustrated in Fig. 93. The proper amount of stock is first forged into a disk, a hole is punched into this disk and a *mandril* inserted. A U-shaped rest is then placed on the anvil of the steam hammer and the mandril laid on this. The ring is turned on the mandril and forged into shape. Larger and larger mandrils are substituted as the hole in the ring increases in size.

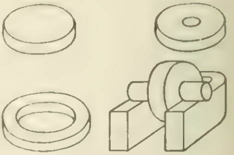


Fig. 93.

Lever with Boss. The following description will serve for many forgings of the same general shape. The forging shown in

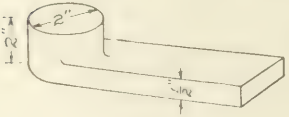


Fig. 94.

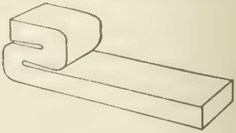


Fig. 95.

Fig 94 will be taken as an example. There are two general ways of making work of this character. One is to take stock of the proper size for the lever and weld on a chunk for the boss. The other is to take stock large enough to form the boss and draw out either the entire lever, or a short stub, to which the lever is welded. The work may be started for the first method by doubling over the end of the stock as illustrated in Fig. 95. This is welded up and rounded by the same general method as afterwards described for the other boss. The second method of shaping is illustrated in Fig. 96. The stock in this case would be two inches square. The fuller cut is first made as illustrated at A. The end is then drawn out into the shape shown at B. In drawing out the stock, if the metal be allowed to flatten down into shape like C, a "cold-shut" will be formed close to the boss, as the corner at X will overlap and work into the metal, making a crack in the work. The proper way to draw out the stock is shown at D. The square piece left for the boss is rounded up over the cor-

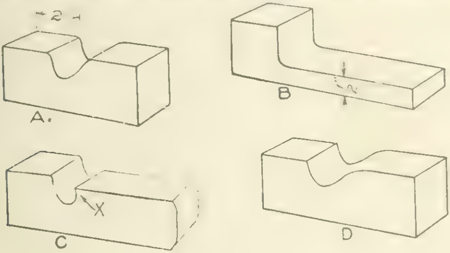


Fig. 96.

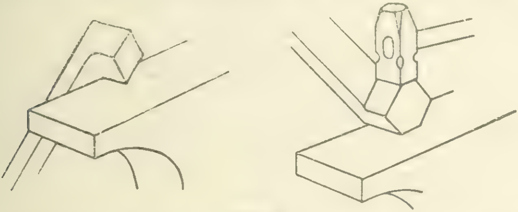


Fig. 97.

ner of the anvil as shown in Fig. 97. Sometimes to make the work easier to get at, the end is bent back out of the way and straightened after the forging is completed. The boss may be smoothed up by using a set hammer or swage in the manner indicated.

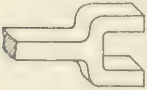


Fig. 98.

Knuckles. One example of a very numerous class of forgings is shown in Fig. 98. This is the shape used for what are known as marine ends of connecting rods, knuckle joints on valve rods, and various other places. A common method employed to make such a forging is shown in Fig. 99. Two fuller cuts are first made as indicated at A and the part for the shaft of the forging drawn out. The thick end is then punched and split, as indicated at B. This split end is opened up and forged out in the manner indicated in Fig. 100, if the work is done on the anvil. Fig. 101 illustrates the method of working out under the steam hammer, the end being first flattened as indicated and then gradually tipped up to the position shown by the dotted lines. When drawn to size, the ends are flattened out straight across and the finishing done around the shank with a fuller as indicated in Fig. 102. The forging is then bent into a U-shaped loop of approximately the shape of the finished knuckle. A bar of iron the same dimension as the inside of the finished knuckle is inserted between the sides of the loop, and the sides closed down flat as shown in Fig. 103. Fig. 104 shows other forgings which may be shaped by this same general method. Trim E, Fig. 99, to the dotted line.

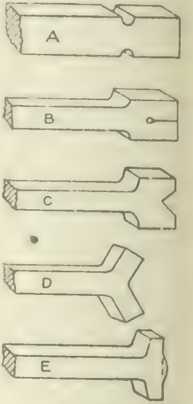


Fig. 99.

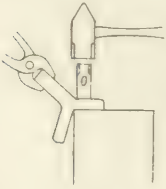


Fig. 100.

Wrenches. A simple tool that is frequently called for is the S wrench. This wrench is usually made with a gap at each end suited for nuts of different sizes. It is shown complete in Fig. 105.

The jaws at the end should be parallel with each other. A line drawn from one jaw to the other should make an angle of 30 degrees with the center line of each. There are two ways in which such a wrench can be forged. One is to forge the jaws separately and then weld to the handle. In the other the jaws are cut from a solid piece of metal and the iron between is then drawn down to the proper size for the handle. The latter is preferable, since it avoids all welds. To make the wrench by the second process, select a piece of steel large enough to form the head. Fuller it down back of the head as shown in A, Fig. 106, at *a a*. Round the end and punch the hole *b*. Next treat the other end in the same way and draw out the intermediate metal giving the form shown at B. Now cut out the holes *b b* securing

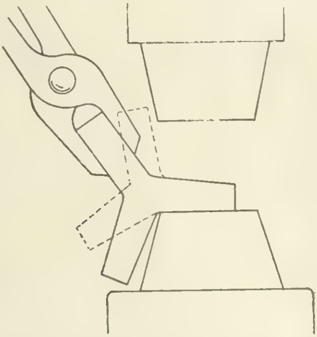


Fig. 101.

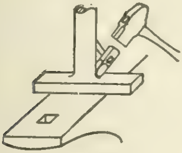


Fig. 102

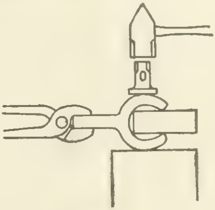


Fig. 103.

the form shown at C. It now remains to bend the heads to the proper angle and give the desired curve to the shank. In forging such a wrench the outer edges should be slightly rounded so that they will not cut the hand The inside of the jaws should be perfectly square with sharp edges. This finish can be best obtained by filing.

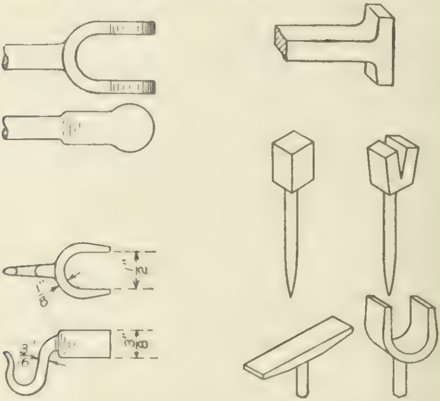


Fig. 104.

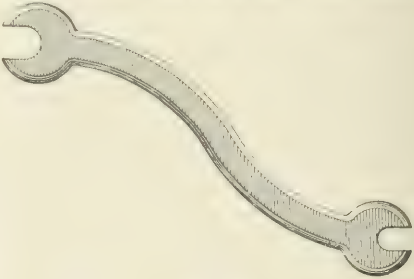


Fig. 105.

Socket Wrenches are made in several ways. The easiest way in "hurry up" work is the method illustrated in Fig. 107. A stub is forged to the same size and shape as the finished hole is to be, and a ring, bent up of thin flat iron, welded round this stub. When finishing the socket, a nut or bolt head of the same size that the wrench is intended to fit, should be placed in the hole and the socket finished over this, between swages. A better way of making wrenches of this kind is to make a forging having the same dimensions as the finished wrench with the socket end left solid. The socket end is then drilled to a depth slightly greater than the socket is wanted. The diameter of the drilled hole should be as shown in Fig. 108, equal to the shortest diameter of the finished hole. After drilling, the socket end is heated and a punch, of the same shape as the finished hole,

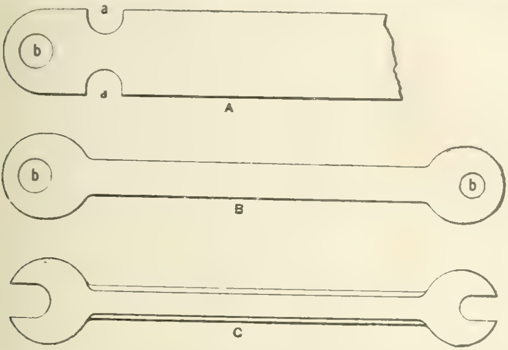


Fig. 106.

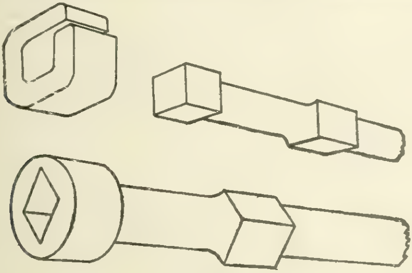


Fig. 107.

driven into it. The end of the punch should be square across and the corners sharp. As the punch is driven in, it will shave off some of the metal around the corners of the hole and force it to the bottom,

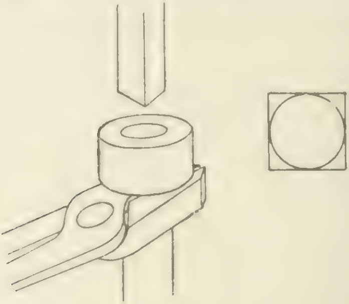


Fig. 108.

thus making it necessary to have the drilled hole slightly deeper than the finished socket.

Ladle Shank. The ladle shank shown in Fig. 109 may be made in several ways. The ring may be welded up of flat stock and a round handle welded on with a T-weld. Or square stock may be taken, worked out and split as shown in Fig. 110, these split ends being afterwards welded to make the ring. Another method of making without any welds at all would be to split the stock as indicated in Fig. 111 and work out in the same way that a weldless ring is made. The latter method would take more time but would make the sounder forging.

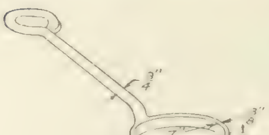


Fig. 109.

Molder's Trowel. The molder's trowel illustrated in Fig. 112 is a sample of a large class of forgings, having a wide, thin face with a comparatively small thin stem forged at one end. The stock used for the trowel would be about $\frac{1}{4}''$ × 1″. This is thick enough to allow for the formation of a ridge at R. Fig. 113 shows the general method employed. Two nicks are first made with fullers as illustrated at A and the stem drawn down, roughly, to size. This stem is then bent up at right angles and forged to a square corner as illus-

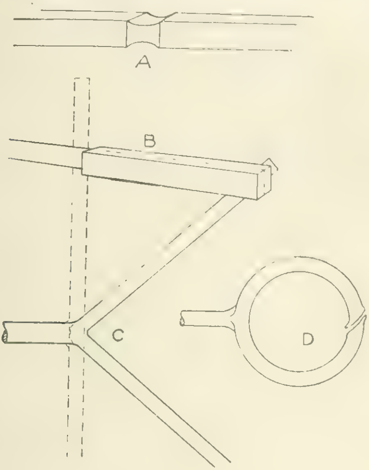


Fig. 110.

trated at B, in the same general manner as the square corner of a bracket is formed. When flattening out the blade in order to leave the ridge shown at R, Fig 112, the work should be held as shown at C, Fig. 113. Here the handle is held pointing downward and against the side of the anvil. By striking down on the work and covering the part directly over the edge of the anvil with the blows, all the metal on the anvil will be flattened down. By swinging the piece around into a reversed position, the other edge of the blade is then thinned down. This leaves the small triangle shown by the dotted lines

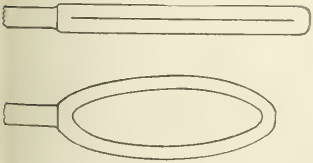


Fig. 111.

unworked and forms the ridge shown at R. The same result could be obtained by placing the work flat on the anvil face and using a set hammer.

TOOL STEEL WORK.

Tool Steel. Although not strictly true technically, for ordinary purposes tool steel may be considered simply a combination of iron and carbon. The more common grade contains perhaps 1 per cent of carbon. Machine steel and wrought iron do not contain this element carbon to any great extent. If a piece of wrought iron or machine steel be heated red hot and suddenly cooled, the metal remains practically as it was before heating, but if a piece of tool steel be subjected to this treatment, it becomes very hard and brittle. By a modification of this heating and cooling, almost any degree of hardness may be imparted to the steel. When tool steel is heated red hot and then suddenly cooled, becoming very hard, the process is known as *Hardening*. For more detailed explanations of hardening, tempering, etc., the student is referred to "Tool Making", as merely general statements and explanations will be given here. If two pieces of tool steel be heated, one to a comparatively high heat and one to a lower heat and the two pieces suddenly cooled in water, if the ends be then snapped off, a decided difference will be noticed in the fractures. The piece cooled from the

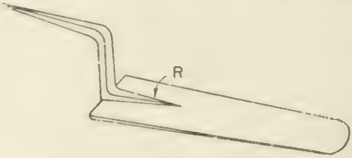


Fig. 112.

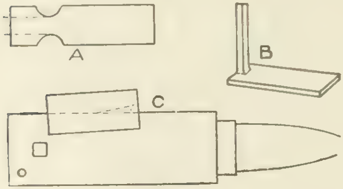


Fig. 113.

higher temperature will have a very coarse grain, while that cooled from the lower temperature will have a finer grain. Two things are fixed when hardening a piece of tool steel—hardness and grain. The hardness depends upon the rapidity with which the steel is cooled. The more rapid the cooling, the harder the steel. The grain depends upon the heat from which the steel is cooled. There is only one heat from which the steel may be cooled and have the proper grain. This heat is known as the *hardening heat*. A piece of steel when cooled from this hardening heat has an extremely fine silky looking grain and is left very hard and brittle.

Hardening. The *hardening heat* varies with the amount of carbon the steel contains, the greater the percentage of carbon, the lower the hardening heat.

To determine the hardening heat, a bar ¼" or ⅜" square is heated to a good red heat on one end, and cooled in cold water. This end is then tested, if too hard to file it has been hardened, and the heat from which it was cooled was either the proper hardening heat or some higher heat. If the end can be filed it was cooled from some heat below the hardening heat. If the end proves to be soft it should be rehardened by cooling from a higher heat, if hard it should be broken off and the fracture examined. If the grain of the broken end is very fine the steel is properly hardened, if coarse, it was heated too hot and the end should be rehardened at a lower heat. The experiment should be repeated until the operator is able to give the steel a very fine grain every time. Any variation either above or below the hardening heat will make the grain coarse. A temperature lower than the critical heat will not make the steel as coarse in structure as a temperature correspondingly higher, but there will be some difference.

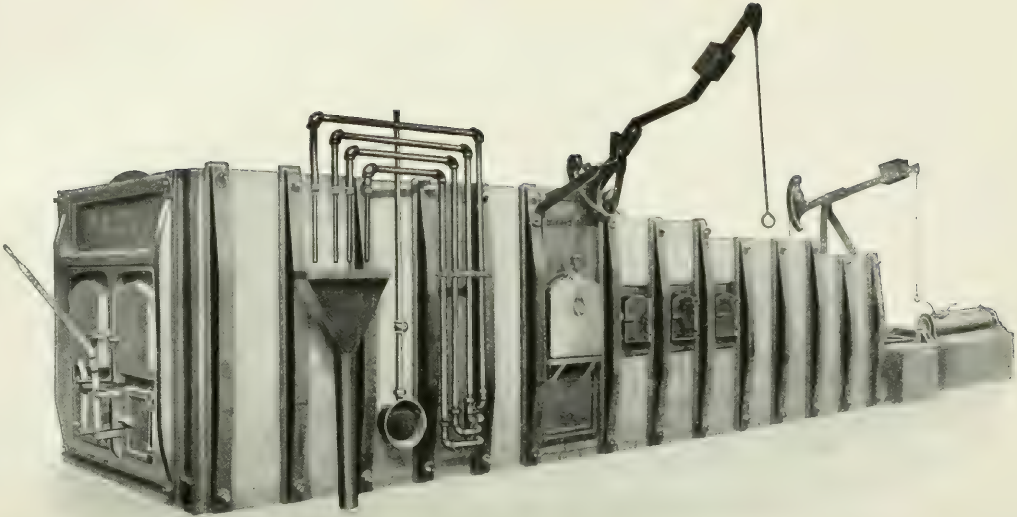
Hardening Baths. Various baths are used for cooling steel when hardening, on account of the different rates at which they cool the heated metal. An oil bath is used when the steel is wanted tougher and not excessively hard, as the oil cools the steel slower than water. Brine or an acid bath are used when the steel is wanted very hard, as they absorb heat more rapidly than water. For excessively hard work mercury or quicksilver, is sometimes used, as it absorbs the heat very rapidly.

General Laws of Hardening. The two simple general facts of hardening that must be remembered are as follows: First, the heat from which the steel is cooled determines the grain; secondly, the rapidity of cooling determines the hardness, everything else being equal, the more rapid the cooling, the harder the steel.

Annealing. When steel is annealed it is softened. This is done by cooling the steel very slowly from the hardening heat, the cooling being done as slowly as possible. This cooling in some cases takes several days. As noted under hardening, the rapidity of cooling determines the final hardness of the steel and if the steel be cooled very slowly it will be left very soft; while if cooled rapidly, it will be left hard. This difference in the time taken to cool the steel is the only difference between hardening and annealing. Both should be done from the same heat. The details of various methods of annealing are described in "Tool Making".

Tempering. Tools which are simply hardened as described above are, with few exceptions, too brittle for use and it is necessary to reduce the brittleness. This process is known as tempering. Tools are always left as hard as it is possible to leave them and still have them tough enough for the work for which they are intended. In reducing the brittleness of the steel, some of the hardness is of necessity taken out and tempering is therefore sometimes spoken of as a reduction of the hardness, but it is in reality, merely a reduction of the brittleness. After a tool or piece of steel has been hardened, some of the brittleness is taken out by a slight reheating to a low temperature. These temperatures vary from 200° F., to about 650° F. These temperatures are determined in various ways. The simplest and perhaps the most commonly used, is to polish the steel after it has been hardened and then reheat the part to be tempered until the surface shows a certain color.

If any bright piece of iron or steel be heated, when a temperature of about 400° F is reached, the surface will turn pale yellow. As the temperature is increased this yellow grows darker until at about 500° F it is a decided brown. When 600° F is reached, a deep blue color shows on the surface. These colors are produced by a thin scale which is formed on the surface of the steel and are no indication whatever of hardness, merely showing to what heat steel or iron has been raised.



AUTOMATIC BILLET-HEATING FURNACE.
Rockwell Engineering Co.

Tempered tools may be divided into two general classes. First, those which have one edge only tempered; second, those which are tempered throughout. To the first class belong most lathe tools, cold chisels, etc. To the second class, taps, dies, milling cutters, etc. When tempering tools of the first class, considerably more of the tool is heated than is wanted hardened. The cutting edge is then hardened by cooling in water. The tool is then taken from the water, the hardened edge polished, and reheated by allowing the heat to "come down" from the body of the tool, which is still quite hot. Tools of the second class are first hardened by being heated to a uniform hardening heat and then cooled completely. The tool is then polished and the temper drawn by placing the steel either over the fire or on a piece of metal which has previously been heated red hot. It is absolutely essential that the steel should be heated to a uniform temperature when hardened. The parts to be hardened should show no difference whatever in color when being heated. If points or corners of tools are allowed to come to the hardening temperature before the body of the tool is hot, these overheated corners are almost sure to crack off. Absolute uniformity in heating to the proper hardening heat is necessary to insure success in hardening operations.

Lead Bath. To insure uniformity in heating, various methods are used, and when the work is done on a large scale the heating is generally done in a furnace fired with gas. Another common method is to heat the steel in a bath of red hot lead. The lead is heated in a pot or crucible, to the hardening heat of the steel. The top of the lead is covered with powdered charcoal or coal to prevent the formation of the slag or dross on top. When steel is heated in lead it must be perfectly clean, dry, and free from rust.

TOOL FORGING AND TEMPERING.

Forging Heat. Before attempting any work with tool steel a piece of scrap steel is to be experimented with, heated and hardened several times at various heats until the manipulator is sure of the effect of the various heats upon the grain of the steel. The steel should also be experimented with to determine just how high a heat it will stand. When heavy forging is to be done, *i. e.*, when the first rough shaping is done upon a tool, a comparatively high heat should be used. The steel should be forged at about what might be called a good yellow heat. The lighter hammering, when finishing, should be done at a lower heat about the hardening heat. Very little, if any, hammering should be done below the hardening heat. If the grain of the steel has been raised by too high a heat, it can generally be quite decidedly reduced by a little hammering at some heat above the hardening temperature.

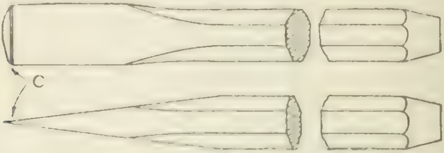


Fig. 114.

Cold Chisels. The stock should be heated to a good yellow heat and forged into shape and finished as smoothly as possible. When properly forged, the end or cutting edge will bulge out as shown in Fig. 114. It is a good plan to simply nick this end across at the point where the finished edge is to come and then after the chisel has been tempered, this nicked end may be broken off and the grain examined. Whenever possible, it is a good plan to leave an end of this sort on a tool that may be broken off after the tempering is done. When hardening, a chisel should be heated red hot about as far back from the cutting edge as the point A, Fig. 115. Care must be taken to heat slowly enough to keep the part being heated at a uniform temperature throughout. If the point becomes overheated, it should not be dipped in water to cool off, but allowed to cool in the air to below the hardening heat and then reheated more carefully. When properly heated, the end should be hardened by dipping in cold water to the point B. As soon as the end is cold, the chisel should be withdrawn from the water and the end polished bright by rubbing with a piece of emery paper. The part of the chisel from A to B will still be red hot

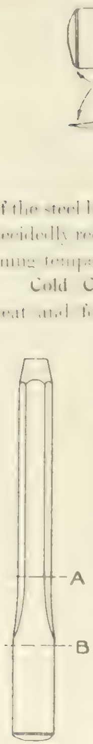


Fig. 115.

and the heat from this part will gradually reheat the hardened point. As this cold part is reheated, the polished surface will change color showing at first yellow, then brown, and at last purple. As soon as the purple (almost blue color) reaches the nick at the end, the chisel should be completely cooled. The waste end may now be snapped off and the grain examined. If the grain is too coarse the tool should be rehardened at a lower temperature, while if the metal is too soft, and the end bends without breaking, it should be rehardened at a higher temperature.

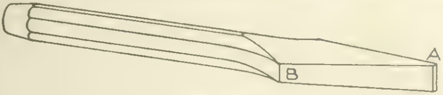


Fig. 116.

Cape Chisel. This is a chisel used for cutting grooves, key seats, etc. The end A should be wider than the rest of the blade back to B, Fig. 116. The chisel is started by thinning down B with two fullers, or over the horn of the anvil as shown at A, Fig. 117. The end is then drawn out and finished with a hammer or flatter in the manner illustrated at B. A cape chisel is given the same temper as a cold chisel.

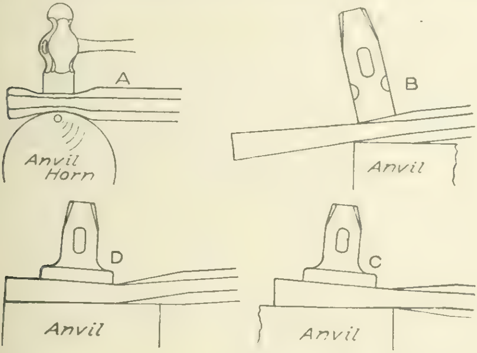


Fig. 117.

Square and Round Nose Chisels. These two chisels, the ends of which are shown in Fig. 118, are forged and tempered in practically the same way as the ordinary cape chisel, the only difference being in the shape of the ends. Round nose cape chisels are sometimes used for centering drills and are then known as centering chisels.

Lathe Tools. The same general forms of lathe tools are used in nearly all shops, but the shapes are altered somewhat to suit individual tastes.

Right Hand and Left Hand Tools. Many lathe tools are made in pairs and are called right and left hand tools. If a tool is made in such a way that the cutting edge comes toward the left hand as the tool is held in position in the lathe, it is known as a *right hand tool, i. e.,* a tool which begins a cut at the right hand end of the piece and moves from right to left is known as a right hand tool. The one commencing at the left hand end and cutting toward the right would be known as a *left hand tool.* The general shape of right and left hand tools for the same use is generally the same excepting that the cutting edges are on opposite sides.

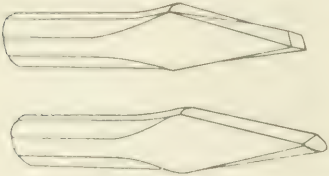


Fig. 118.

Clearance. When making all lathe tools, care must be taken to see that they have proper clearance, *i. e.*, the cutting edge must project beyond or outside of the other parts of the tool. In other words, the sides of the tool must be undercut or slant downwards and backwards away from the cutting edge. This is illustrated in the section A B of Fig. 119, where the lower edge of the tool is made considerably

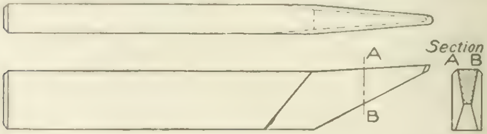


Fig. 119.

thinner than the upper edge, in order to give the proper clearance.

Round Nose and Thread Tools. These tools are practically alike excepting for a slight difference in the way the ends are ground. The general shape is shown in Fig. 119. When hardening, the tools should be heated about as far as the line A, Fig. 120, and cooled up to the line B. The temper is then drawn in the same general way as described for tempering of cold chisels excepting that when a light yellow color shows at the cutting edge the tool is cooled for the second time. All lathe tools are given practically the same temper. Sometimes tools are left much harder. In one quite well known plant the tools are simply reheated until the water evaporates from the cutting end, indicating a reheating to a temperature of about 200°F.

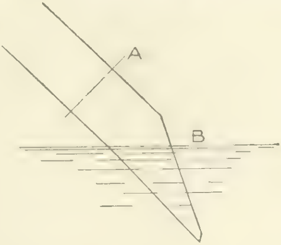


Fig. 120.

Cutting off Tools are forged with the blade either on one side or in the center of the stock. The easier way to make them is to forge the blade with one side flush with the side of the tool. Such a tool is shown in Fig. 121. The cutting edge, A, the extreme tip of the blade, should be wider than any other part of the thinned end, B. In other words, this edge should have clearance in all directions as indicated in the drawing. The clearance angle at the end of the tool as shown in the sketch, is about correct for lathe tools. For heavier tools for the planer, the angle should be as shown by the line X X. When hardening, the end of the tool should be heated to about point C C and cooled to about the line D D, and the temper drawn as described for the round nose tool. Tools may be forged in the general way shown in Fig. 122. The tool is started by making a fuller cut as shown

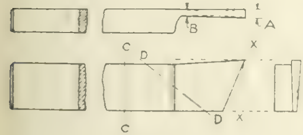


Fig. 121

at A. After roughly shaping, the end is trimmed off with a hot chisel along the dotted line at C. Great care must be taken to see that the blade of the tool has proper clearance in all directions.

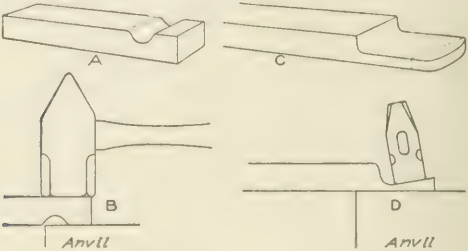


Fig. 122.

When a tool is wanted with a blade forged in the center, it should be first started by using two fullers instead of one, then making two cuts, one on each side of the stock, in place of the single cut shown at A.

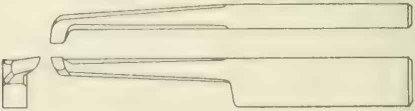


Fig. 123.

Boring Tool. The general shape of this tool is shown in Fig. 123. The length of the thin end depends upon the depth of the hole in which the tool is to be used and as a general rule should be made as short and thick as possible, in order to avoid springing. The tool may be started in the same general way as the cutting off tool, the fuller cut being made on the edge of the stock instead of on the side. The cutting edge of the tool is at the end of the small "nose," and this "nose" is the only part which should be tempered.

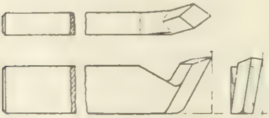


Fig. 124.

Diamond Points. These tools are made in a variety of modifications of the shape shown in Fig. 124. There are various methods used for shaping them, one of which is illustrated in Fig. 125. The shape is started as indicated at A. After the nick has been made as shown, the end of the tool is shaped as shown by the dotted lines, the blows coming in the direction of the arrow. Further shaping is done as indicated at B. To square up the end of the nose of the tool, it is worked backward and forward as indicated at C. The tool is finished by trimming off the end to the proper angle with a hot chisel and touching it up with a set hammer. When hardened it should be dipped about as shown at D.

Side Tools or side finishing tools as they are sometimes called, are generally made in about the shape shown at F, Fig. 126. The tool may be started by making a fuller cut as shown at A. The end x is then drawn out with a fuller into the shape B. After smoothing up with a set hammer the blade is trued into shape along the dotted lines at C. The tool is finished by giving the proper "*offset*" to the top edge of the blade. This is done by placing the tool flat side down with the blade extending over, and the end of the blade next the shank about ⅛" beyond, the outside edge of the anvil. A set hammer is placed on the blade close up to the shoulder and slightly tipped, so that the face of

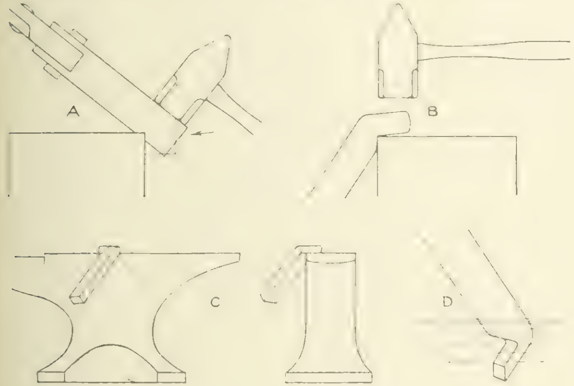


Fig. 125.

the hammer touches the thin edge of the blade only, as illustrated at D. One or two light blows with the sledge will give the necessary offset and after touching up the blade, the tool is ready for tempering. When heating for hardening, the tool should be placed in the fire with

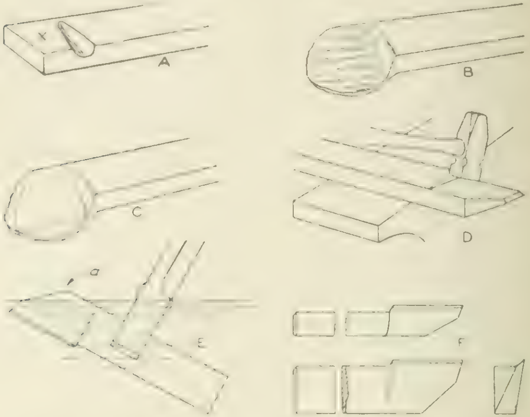


Fig. 126.

the cutting edge *up*. In this way it is more easy to avoid overheating the edge. The hardening should be done by dipping the tool in water as illustrated at E, only the small part A being left above the surface. The tool is taken from the water, quickly rubbed bright

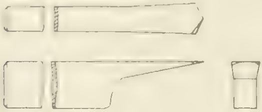


Fig. 127

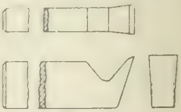


Fig. 128

on the flat side, and the temper drawn until the cutting edge shows a light yellow. The same color should show the entire length of the cutting edge. If the color shows darker at one end, it indicates that that end of the blade was not cooled enough and the tool should be rehardened, this time dipping the tool in such a way as to bring that end of the blade which was too soft before, deeper in the water.

Centering Tool. The centering tool shown in Fig. 127 is used for starting holes on face-plate and chuck work. The end may be shaped by making a fuller cut and then flattening out the metal, trimming the cutting edge to shape with the hot chisel.

Forming Tools for Turret Lathes are sometimes forged up in the same general shape as above and tempered like other lathe tools.

Finishing Tool. This tool, Fig. 128, may be started either with a fuller cut or in the same way as the diamond point. The end is then flattened out and shaped with a set hammer as shown in Fig. 129. This generally leaves the end bent out too nearly straight, but it may be easily bent back into shape as indicated at B. This bending will probably leave the point something like C. A few blows of the hammer at the point indicated by the arrow will give the tool the shape as at D. The cutting edge should be tempered the same as other lathe tools. For planer and shaper tools of this shape, the end should be more nearly at right angles to the edge of the tool, making an angle of about six or eight degrees less than the perpendicular. In other words, the tool should have less end rake.

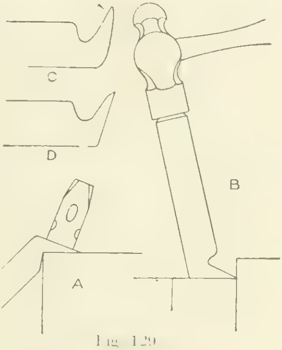


Fig. 129

Flat Drills need no particular description as to forging and shaping. The size of the drill is determined by the width of the flat end, this being the same size as the hole the drill is intended to bore. If this dimension were one inch, the drill would be known as a one-inch drill. The drill should be made somewhat softer than lathe tools, the temper being drawn until a light brown shows at the cutting edge.

Springs are generally tempered in oil. The spring is heated to a uniform hardening heat and hardened by cooling in oil. The temper is drawn by holding the spring, still covered with oil over the flame of the forge, and heating until the oil burns over the entire spring. If the spring is not uniform in section throughout, it is generally advisable, while heating it, to plunge every few seconds into the oil bath, taking it out instantly and continuing the heating. This momentary plunge tends to equalize the heat by cooling the thinner parts.

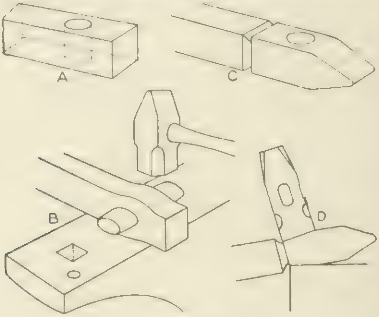


Fig. 130

Lard oil or fish oil are generally used as mineral oil is too uncertain in composition. The above method of tempering is known as *blazing off*, the blazing point of the oil being used to indicate the temperature in place of the color of the scale. The same results could be obtained by polishing the spring and heating until it turned blue.

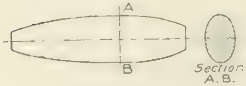


Fig. 131.

Hammers. When making a hammer the stock should be taken large enough to make the largest part of the hammer without any upsetting. As a general rule the hammer is forged on the end of a bar and finished as completely as possible before cutting off.

Riveting Hammer. About the easiest hammer to shape is the riveting hammer shown at D, Fig. 4. This hammer, as well as all other hammers, is started by first punching the hole for the eye as shown at A, Fig. 130. When the eye is punched the stock is generally bulged out sideways and in order to hold the shape of the eye while flattening down this bulge, a drift pin such as shown in Fig. 131 is used. This pin is made larger in the center and tapering at both ends. The center or larger part of the pin has the same shape as the finished eye of the hammer. This pin is driven into the punched hole and the sides of the eye forged into shape as illustrated at B, Fig. 130. After the eye has been properly shaped, the next step is to shape down the tapering pene leaving the work, after a nick has been made around the bar where the face of the hammer will come, as shown at C. The end of the hammer toward the face is then slightly tapered in the manner indicated at D. After the hammer has been as nearly as possible finished, it is cut from the bar and the face trued up. For tempering, the whole hammer is heated to an even hardening heat. The hammer is then grasped by placing one jaw of the tongs through the eye. Both ends are tempered, this being done by hardeneng first one end and then the other. The small end is first hardened by dipping in the water as shown at Fig. 132. As soon as this end is cooled the position of the hammer is instantly reversed and the face end hardened. While the large end is in the water the smaller end is polished and the temper color watched for. When a dark brown scale appears on the small end the hammer is again reversed bringing the large end uppermost and the pene in the water. The face end is then polished and the temper drawn. If the large end is properly hardened before the temper color appears on the small end, the hammer may be taken completely out of the water, the large end polished, and the colors watched for on both ends at once. As soon as one end shows the proper color it is promptly dipped in water, the other end following as soon as the color appears there, but under no circumstances should the eye be cooled while still red hot. For some special work hammer faces should be left harder, but for ordinary use the temper as given above, is very satisfactory.

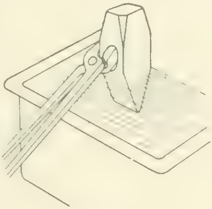


Fig. 132.

Ball Pene Hammer. The general method of making this hammer is illustrated in Fig. 133. After punching the hole, the hammer is roughed out by using the fullers as shown at A and B. The ball end is then rounded up, the octagonal parts shaped with the fullers and the hammer cut from the bar, ground and tempered. Ball peen hammers may be made with a steam hammer in practically the same way as described above, excepting that round bars of steel should be substituted for the fullers.

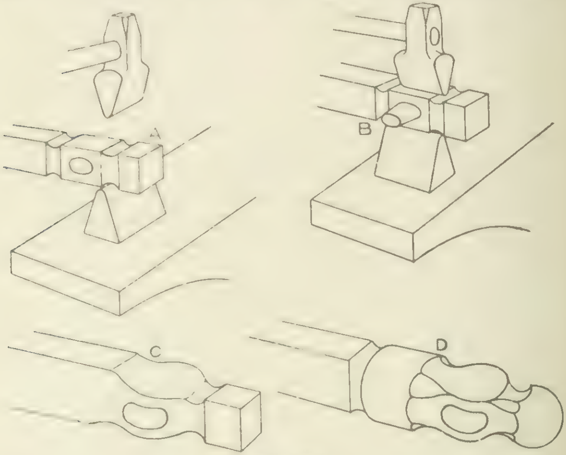


Fig. 133

Blacksmith's Tools such as cold chisels, hot chisels, set hammers and flatters are made in much the same way as hammers. The wide face of the flatters may be upset by using a block such as is shown in Fig. 134. The heated end of the tool is dropped into the hole in the block and the face upset into the wide shallow opening. Swages may also be worked up in this way.

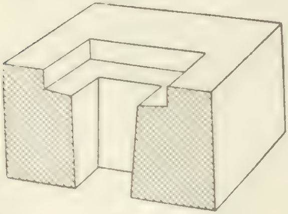


Fig. 134

Self-hardening Steel is used to a large extent in modern practice for lathe tools, much being used in the shape of small square steel held in special holders. Such a tool is illustrated in Fig. 135. Self-hardening steel, as its name indicates, is almost self-hardening in nature, generally the only treatment that is required to harden the steel being to heat it red hot and allow it to cool. Sometimes the steel is cooled in an air blast or is dipped in oil. It is not necessary to "draw the temper". The self-hardening quality of steel is given to it by the addition of Chromium, Molybdenyum, Tungsten, or one of that group of elements, in addition to the carbon which ordinary tool steel contains. Self-hardening steel is comparatively expensive, costing from 40 cents and upwards per pound, some of the more expensive grades costing $1.00 or so. When in use, self-hardening steel will stand a much higher cutting speed than the ordinary so-called carbon steel. For this reason it is much more economical to use, although its first cost is higher. Self-hardening steel cannot be cut with a cold chisel and must be either cut hot or nicked with an emery wheel and snapped off. Great care must be used in forging it, as the range of temperature through which it may be forged is comparatively slight, running from a good red heat to a yellow heat. Some grades of self-hardening steel may be annealed by heating the steel to a high heat in the center of a good fire and allowing the fire and the steel to cool off together. Steel which has been annealed in this way may be hardened by heating to the hardening heat and cooling in oil.

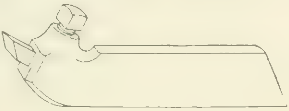


Fig. 135.

Taylor-White Process. This method of treating special grades of self-hardening steel was discovered some years ago by the men after whom it is named. It was found that if a piece of self-hardening steel be heated to a very high temperature (about the welding heat) and then suddenly cooled to about a low red heat, the steel would be in a condition to stand very much harder usage and take a much heavier cut. Steel treated in this way seemed to have the cutting edge of the tools almost burned or melted off and considerable grinding was necessary to bring them into shape. When put in use the edges would almost immediately be slightly rounded or crumble off, but after this slight breaking down of the cutting edge, the steel would stand up under excessively trying conditions of high speed and heavy cut. Tools of this character were of very little, or no, use for fine finishing, but were of great value for heavy and roughing cuts.

HEAVY FORGING.

Steam Hammer. An ordinary form of steam hammer is shown in Fig. 136. Its essential parts are an inverted steam cylinder, to whose piston rod the hammer head is attached, and the frame for carrying the whole. The hammer is raised by admitting steam beneath the piston. The blow is dealt by exhausting the steam from beneath the piston and admitting it above the same. The head is thus accelerated by gravity and the pressure of steam above the piston. The valve gear is so arranged that the intensity of the blow may be varied by changing the amount of steam admitted to the piston on its downward stroke. The steam admitted below on the same stroke forms a cushion for the absorption of the momentum of the head. In this way the lightest of taps and the heaviest of blows can be deliv-

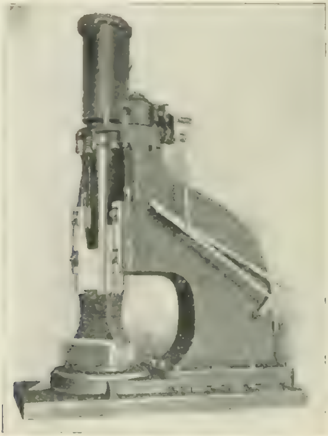


Fig. 136.

ered by the same hammer. These hammers are also made in a great variety of sizes. Steam hammers are rated by the weight of the falling parts, *i. e.*, the piston rod, ram or head, and hammer die. A hammer in which these parts weigh 400 lbs. would be called a 400 lb. hammer. Steam hammers are made in two distinct parts: the *frame*, carrying the hammer or ram, and the *anvil*, on which the hammer strikes.

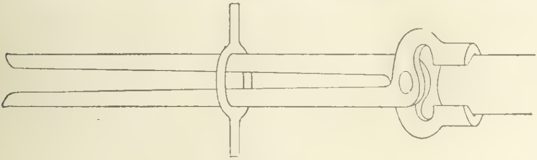


Fig. 137.

The frame is carried on a heavy foundation, and the heavy anvil, which is generally made of cast iron and fitted with a die block of tool steel, rests upon a heavier foundation of timber or masonry capped with a timber. The object of these separate foundations is to allow the anvil to give slightly under a blow without disturbing the frame. On very light power hammers the anvil and frame are sometimes made together.

Hammer Dies. The dies, as most commonly used with a steam

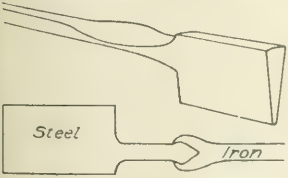


Fig. 138.

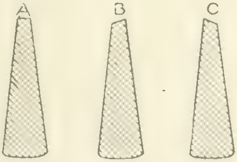


Fig. 139.

hammer, have flat faces. The best ones are made of tool steel. These dies may be made of tool steel and left unhardened, then when the dies become battered out of shape from use, they may be trued up and refaced without going to the trouble of annealing and hardening. Dies of gray cast iron and cast iron with a chilled face are also quite commonly used. Ordinary gray cast iron is used, particularly when special shaped dies are employed for welding and light bending.

Tongs for steam hammer work should always carefully be fitted and should grip the stock firmly on at least three sides. A quite common shape for tongs for heavy work is shown in Fig. 137. To hold the tongs securely on the work and to make it easier to handle them, a link is sometimes used of the shape shown. This is driven firmly over the handles of the tongs and the projecting ends are used as handles for turning the work.

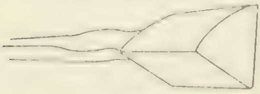


Fig. 140

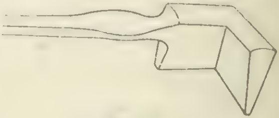


Fig. 141

Hammer Chisels. The common shape for hot chisels for use under the steam hammer is given in Fig. 138. The handle and blade are sometimes made from one piece of tool steel. Sometimes the blade is made of tool steel and an iron handle welded on as shown in the sketch. The handle next to the blade should be flattened out to form sort of a spring which permits a little give when using the chisel. The edge of the chisel should be left square across and not rounding. The proper shape is shown at A, Fig. 139. Sometimes for special work the edge may be slightly beveled as at B or C. For cutting or nicking bars cold, a chisel similar in shape to Fig. 140 is sometimes used. This is made very flat and stumpy to resist the crushing effect of heavy blows. For cutting into corners a chisel similar in shape to Fig. 141 is sometimes used. For bent or irregular work the chisel may be formed accordingly. For cutting off hot stock the method used is about as illustrated in Fig. 142, *i. e.*, the work is cut nearly through as shown at A. The bar is then turned over and a thin strip of steel with square corners placed on top as shown at B.

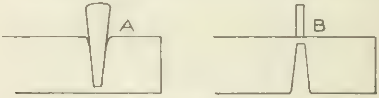


Fig. 142

A quick heavy blow of the hammer drives this steel bar through the work and carries away the thin fin shown, leaving both of the cut ends clean and smooth.

Tools. The tools used for steam hammer work are generally very simple. Swages for finishing work up to three or four inches in diameter are commonly made in the shape shown in Fig. 143.

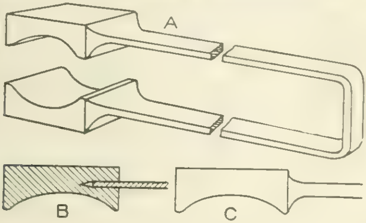


Fig. 143.

The handle is made in the shape of a spring and may be either made in one piece with the blocks and drawn out as shown at C, or may be inserted as shown at B. This sort of a tool is known as a spring tool. Another sort of swage sometimes used, is illustrated in Fig. 144, the top swage at A, the bottom swage at B. This sort of a swage is used on a die block which has a square hole cut in its face similar to the hardy hole in an anvil. The short horn X, of the swage, fits into this hole, the other two projections coming over the side of the anvil block.

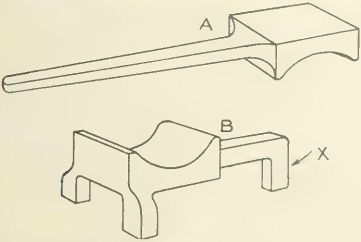


Fig. 144.

Tapering and Fullering Tool. The faces of the anvil and hammer dies are flat and parallel and it is, of course, impossible to finish tapering work smooth between the bare dies. This work may be done by using a tool similar to Fig. 145. Its method of use is shown in Fig. 146, the roughing being done with the round side down and the finishing with the flat side. Fullers used for ordinary hand forgings are seldom employed in steam hammer work. Round bars are used in their place in the manner illustrated in Fig. 147. If a nick is wanted on one side only, simply one round bar is used. Care must always be taken to be sure that the work is in the proper position before striking a heavy blow with the hammer. To do this the hammer should be brought down lightly on the work thus bringing the piece to a flat "bearing" for the first blow.

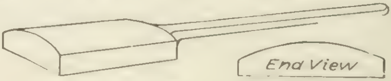


Fig. 145.

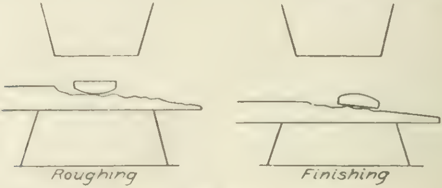


Fig. 146.

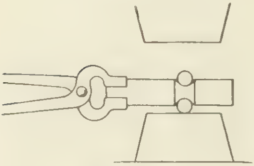


Fig. 147.

Squaring up Work. It frequently happens that work is knocked lopsided under the hammer, being worked up into some such shape as shown at A, Fig. 148. To correct this and bring the work up square, the bar should be put under the hammer and there knocked into shape B and then rolled in the direction indicated by the arrow until shaped as at C when it may then be worked down square and finished like D.

Crank Shafts. The crank shaft shown in Figs. 82 and 83 is quite a common example of steam hammer work. The stock is first worked as illustrated in Fig. 149, the cuts being on each side of the crank cheek. A special tool is used for this as illustrated. When the cuts are very deep, they should first be made with a hot chisel and then opened up with this spreading tool. With light cuts, however, both operations may be done with a spreading tool at the same time. Care must be taken, when flattening out the ends, to prevent any of the material from doubling over and forming a "cold shut". After the ends are hammered out, the corners next to the cheeks may be squared by using a block as shown in Fig. 85.

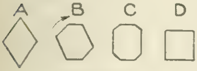


Fig. 148.

Connecting Rod: *Drawing out between the shoulders.* The forging illustrated in Fig. 80, while hardly the exact proportions of the connecting rod, is near enough the proper shape to give a good example of this kind of forging. The work is first started by making two cuts as illustrated in Fig. 150. The metal between the two cuts is then drawn out by using two steel blocks as shown in Fig. 151 until the metal is stretched long enough to allow the corners of the square ends to clear the edges of the hammer dies, when the work is done directly upon the bare die.

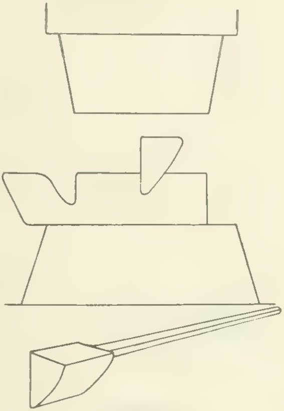


Fig. 149

MISCELLANEOUS PROCESSES.

Shrinking. When iron is heated it expands and upon being cooled it contracts to about its original size. This property is utilized in doing what is known as *shrinking*. Fig. 152 shows a collar *shrunk* on a shaft. The collar and shaft are made separate, the hole through the collar being slightly less in diameter than the outside diameter of the shaft. The collar is then heated red hot and the heat causes the collar to expand, making the hole larger in diameter than the shaft. The collar, while still hot, is then placed on the shaft in proper position, and cooled as quickly as possible by pouring water on it. As the collar is cooled it contracts and squeezes, or locks, itself firmly in position. This principle of shrinking is used to a large extent where a firm, tight fit is wanted, the only objection being that it is rather difficult to take a piece off after it has once been shrunk into place.

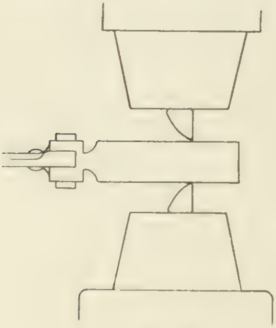


Fig. 150

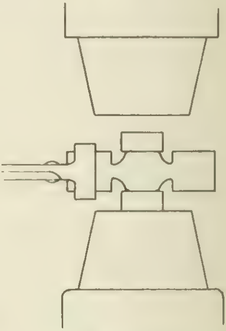


Fig. 151

Brazing. When two pieces of iron or steel are welded together, they are joined by making the pieces so hot that the particles of one piece will stick to those of the other, no medium being used to join them. In brazing, however, the brass acts in joining two pieces of metal together in somewhat the same manner that glue does in joining two pieces of wood. Briefly the process is as follows: The surfaces

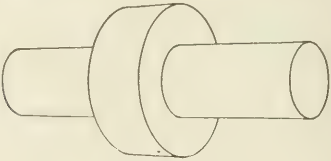


Fig. 152.

to be joined are cleaned, held together by a suitable clamp, heated to the temperature of melting brass, flux added, and the brass melted into the joint. The brass used is generally in the shape of "spelter". This is a finely granulated brass which melts at a comparatively low temperature. "Spelter" comes in several grades designated by hard, soft, etc., the harder spelters melting at higher heat but making a stronger joint. Brass wire or strips of rolled brass are sometimes used in place of spelter, brass wire in particular being very convenient in many places. A simple example of a brazed joint is shown in Fig. 153, where a flange is brazed to the end of a small pipe. It is not necessary in this case to use any clamps as the pieces will hold themselves together. The joint between the two should be made roughly. If a tight joint be used there will be no chance for the brass to run in. The joint should fit in spots but not all around. Before putting the two pieces together, the surfaces to be joined should be cleaned free from loose dirt and scale. When ready for brazing the joint is smeared with a flux (one part salammoniac, six or eight parts borax) which may be added dry or put on in the form of a paste mixed with water. The joint is then heated and the spelter mixed with flux sprinkled on and melted into place. Brass wire could be used in place of the spelter in the manner indicated, the wire being bent into a ring and laid round the joint as shown. Ordinary borax may be used as a flux, although not as good as the mixture used above. The heat should be gradu-

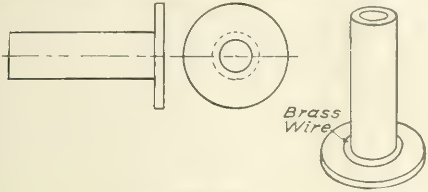


Fig. 153.

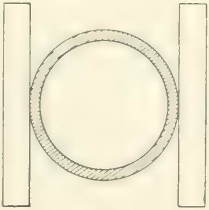


Fig. 154.

ally raised until the brass melts and runs all around and into the joint, when the piece should be lifted from the fire and thoroughly cleaned by scraping off the melted borax and scale. It is necessary to remove the borax, as it leaves a hard glassy scale which is particularly disagreeable if any filing or finishing has to be done to the joint. This scale may be loosened by plunging the work while still red hot, into cold water. Almost any metal that will stand the heat, may be brazed. Great care must be used in brazing cast iron to have the surfaces in contact properly cleaned to start with, and then properly protected from the oxidizing influences of the air and fire while being heated.

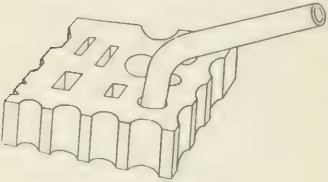


Fig. 155

Annealing Copper and Brass may be done by heating the metals to a red heat and then cooling suddenly in cold water. When copper or brass is hammered to any extent, it becomes hard and springy and if it has to be further worked, it must be annealed or softened, otherwise it is almost sure to split.

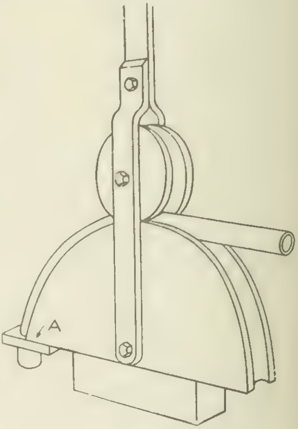


Fig. 156

Bending Cast Iron. It is sometimes necessary to straighten a casting which has become warped or twisted. Cast iron may be twisted or bent to quite an extent if worked cautiously. The bending may generally be done at about the ordinary hardening heat of tool steel and should be done by a steadily applied pressure, not by blows. There is more danger of breaking the work by working it at too high a heat than by working at too low. As an example of how iron may be twisted, a bar of gray cast iron one inch square and a foot long may be twisted through about 90°, before it will break.

Case-Hardening. The essential difference between machine steel and tool steel is the amount of carbon that they contain. If carbon be added to machine steel it will be turned into tool steel. Sometimes articles are wanted very hard on the surface to resist wear and at the same time very tough to withstand shocks. If the piece be made of tool steel in order to be hard enough, it will be too brittle, and if made of machine steel in order to be tough enough, will be too soft. To overcome this difficulty the parts are made of machine steel and then the outside is carbonized or converted into tool steel to a slight depth, and this outside coating of tool steel then hardened. The process is known as *case-hardening.* The method used generally consists of heating the machine steel red hot in contact with something very rich in carbon, generally ground bone. The surface of the machine steel takes up or absorbs the carbon and is converted into tool steel. For more detailed information the reader is referred to "Tool Making".

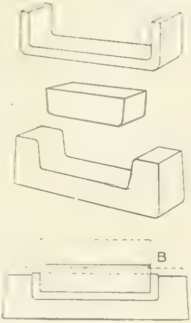


Fig. 157.

Pipe Bending. A piece of pipe when bent always has a tendency to collapse and if this collapsing can be prevented by keeping the sides of the pipe from spreading, a pipe may be successfully bent into almost any shape. One way of doing this would be to bend the pipe between two flat plates as shown in Fig. 154, the plates being the same distance apart as the outside diameter of the pipe. In bending large pipe, the sides are sometimes prevented from bulging by working in with a flatter. Where a single piece is to be bent, it may be done by heating the pipe and inserting one end in one of the holes in a swage block as shown in Fig. 155, the pipe being then bent by bearing down on the free end. As soon as a slight bend is made it is generally necessary to lay the pipe flat on the anvil and work down the bulge with a flatter. Where many pieces are to be bent, a grooved "jig" such as shown in Fig. 156 is sometimes used. The jig is of such a shape that the pipe is completely surrounded where it is being bent, thus not having any opportunity to collapse or bulge. Pipe is sometimes filled full of sand for bending. This helps to some extent. Care must be taken to see that the pipe is *full* and that the ends are solidly plugged. For bending thin copper tubing, it may be filled with melted rosin. This gives very satisfactory results for this character of work. After bending, the rosin is removed by simply heating the pipe.

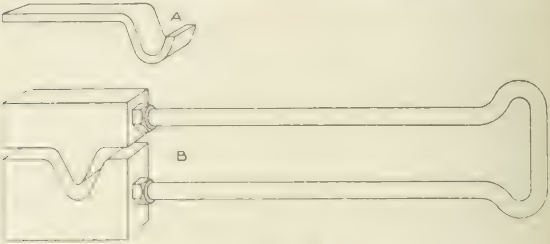


Fig. 158.

Duplicate Work. Where several pieces are to be exactly alike in a shop that is not equipped for special work, it is sometimes practical to use a "jig" for performing the operations. For simple bending the "jig" may consist of a set of cast-iron blocks. Fig. 157 illustrates a simple bend with the block used for doing the work. The work is done as shown at B. The piece to be bent is placed, as shown by the dotted lines, with the bending block on top. The bending is done by one or two strokes of the steam hammer. For convenience in handling, the bending blocks are sometimes held by a spring handle as shown in Fig. 158. The blocks in this case are for bending the hooks shown at A. The handle is simply a piece of

Fig. 159.

½″ round iron with the ends screwed into the cast-iron blocks and held firmly by the lock nuts shown. This makes a cheap arrangement for a variety of work, as the same handles may be used on various sets of

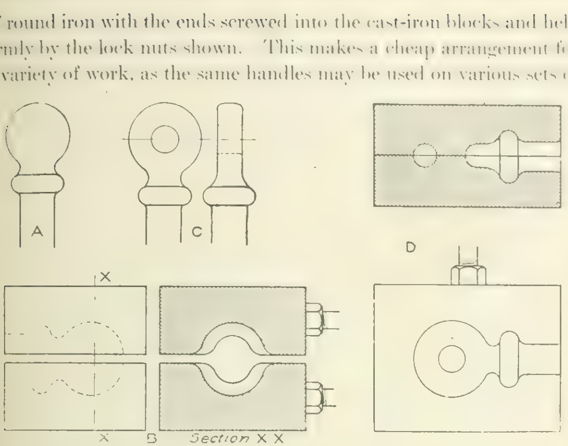


Fig. 160.

blocks. Where a great number of pieces are to be made, these blocks or bending dies may be made of such a shape that they can be keyed on the steam hammer in place of the regular flat dies.

Die Forging. Pieces are sometimes shaped between formed steel dies where many are to be made exactly alike. An example of this sort of work is the eye bolt, Fig. 159. Round stock is used and is first shaped like A, Fig. 160. The shaping is done in the dies shown at B, which are simply two small blocks of tool steel fastened together with a spring handle, the inside faces of the blocks being formed to shape the piece as shown. The end of the bar is heated, placed between the dies blocks and hammered until it takes the required shape, being turned through about 90° between each two blows of the steam hammer, and the hammering continued until the die faces just touch.

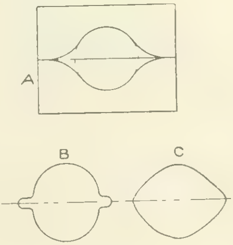


Fig. 161

For the second step the ball is flattened to about the thickness of the finished eye and the hole punched under the steam hammer with an ordinary punch, leaving the work as shown at C. The final shaping is done with the finishing die D. This die is so shaped that when the two parts are together, the hole left is exactly the shape of the finished forging. In the first die it will be noticed that the holes do not conform exactly to the desired shape of the forging, being, instead of semicircular, considerably rounded off at the edges. This is shown more clearly in Fig. 161 at A, where the dotted lines show the shape of the forging, the solid lines the shape of the die. The object of the above is this: If the hole is semicircular in section, the stock, being larger than the smaller parts of the hole, after a blow will be left like B, the metal being forced out between the flat faces of the die and forming fins. When the bar is turned these fins are worked back and make a

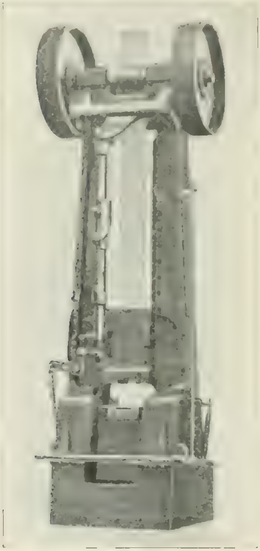


Fig. 162.

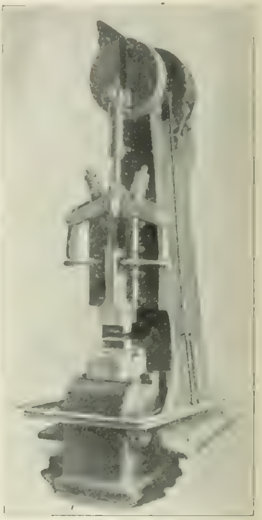


Fig. 163

"cold shut". When the hole is a modified semicircle the stock will be formed like C, and may be turned and worked without danger of "cold shuts". Dies for this kind of work are sometimes made of cast iron. When made of tool steel it is sometimes possible to shape them hot. A "master" forging is first make of tool steel to exactly the shape of the required forging. The blocks for the dies are then forged with flat faces. These blocks are fastened to the handle and then heated red hot. The master forging is then placed between the dies and the dies hammered down tight over the forging. This leaves a cavity just the shape for the required forging.

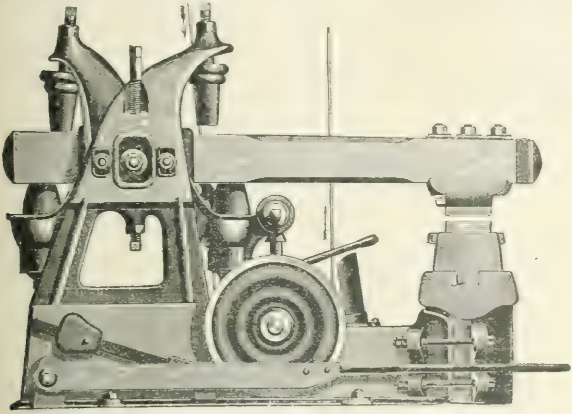


Fig. 161.

MANUFACTURING.

The manufacturing shop differs very essentially from the jobbing shop. In the latter shop very few forgings are made at the same time exactly alike, while in manufacturing, each forging is generally duplicated a large number of times and special machines are used for doing the work.

Drop Forges are used for quickly forming complicated shapes out of wrought iron or steel. They consist, as the name indicates, of a head that may be "dropped" from any desired height upon the piece to be shaped. The head of the drop and the anvil are in the form of dies. As they come together the metal is forced to flow so as to fill the interstices and thus take on the form desired. In drop forging the metal must be heated to a high temperature so as to be in a soft and plastic condition.

A common type of drop hammer used for this kind of work is is shown in Fig. 162. The hammer in this case is fastened to a board and is raised by the friction rollers at the top of the frame being pressed against the board. When the hammer reaches the top of the frame it is dropped by releasing the rollers from the board. This may be done automatically or by a foot treadle. Drop hammers are also built in the same general way as steam hammers. Dies for drop forging generally consist of a roughing or breaking-down die where the rough stock is first given approximately the desired shape and a smoothing die when the finishing is done. These dies have in their faces, holes of the same shape as the required forging.

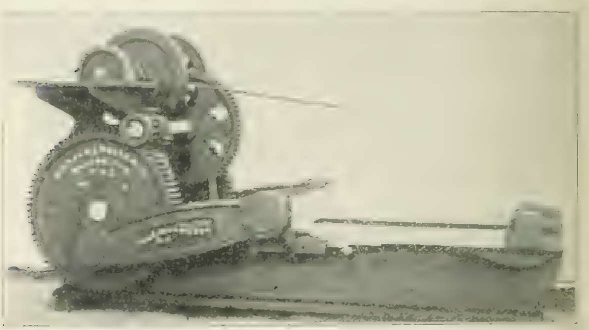


Fig. 165.

Power Hammers. Another tool which is used to quite a large extent in manufacturing as well as in the jobbing shop is the power hammer. This is made in several different types and is used where a quick, rapid blow is wanted. These hammers are run by belts. Two general types are shown in Figs. 163 and 164 The first is known as a justice hammer. The second is a Bradley. Shaped dies are frequently used on these hammers.

Bulldozer. This is a tool used for bending and consists of a heavy cast-iron bed with a block or bolster at one end, and a moving head which slides back and forth on the bed. A common type is shown in Fig. 165. Heavy dies are clamped against the bolster and on the moving head, of such a shape and in such a way that when the moving head is nearest the bolster, the shape left between the two dies is exactly the shape to which it is desired to bend the stock. In operation, the moving head slides back and forth on the bed. The bar to be bent is heated and placed between the dies when the head is farthest from the bolster. A clutch is then thrown in and the head moves forward to the bolster, bending the iron as it goes.

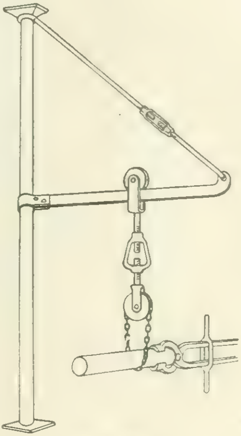


Fig. 166.

Presses serve the same purpose as drop hammers. They do the work more slowly, however. The class of work is, in some respects, the same. The principal difference lies in peculiarities of shape that require different time intervals for the flow of the metal. Where the shape is such that the metal must move slowly in order to acquire its new shape or fill the die, the press should be used.

Flanging Press. A particular type of forging press is the flanging press. This is used more particularly in boiler work and is generally a heavy hydraulic press. The flanging is done by placing the heated metal on the bed of the press and closing the dies together by hydraulic pressure.

Cranes. Where heavy work is to be handled, it is necessary to have some means of conveying the work from one part of the shop to another. This is done by means of cranes of two general types. The traveling crane and jib crane. The former type runs on an overhead track from one end of the shop to the other, generally. The latter type is used more commonly for handling work under the hammers, and is merely an arm or boom swinging around a post and having a suitable arrangement for raising and lowering the work. When handling heavy work, whenever possible, it is suspended from the crane by its center, in such a way that it nearly balances. The suspending is generally done by means of an endless chain such as illustrated in Fig. 166, and in this way it may be easily rolled and swung from side to side. For ease in handling large forgings, a bar, or handle is sometimes welded on. This is known as a porter bar.

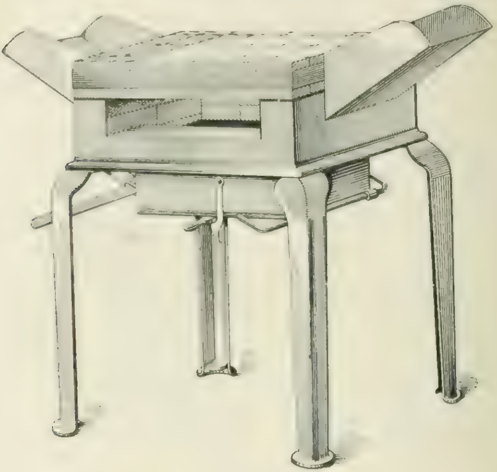


Fig. 167.

Furnaces. In nearly all manufacturing work and in large work in the jobbing shop, the heating is done in furnaces. The heat is generally supplied by either hard coal, coke or oil, coke being more commonly employed in jobbing shops. Sometimes ordinary coal is used. A furnace used for heating small work for manufacturing is shown in Fig. 167. This may be used with either ordinary coal or coke.

Gas Furnaces are used when an even heat is wanted, particularly for hardening and tempering. For manufacturing work the furnaces are sometimes fixed to do the heating automatically. The pieces to be hardened are carried through the furnace on an endless chain which moves at a speed so timed that the pieces have just time enough to be heated to the right temperature as they pass through the furnace. Such a furnace is shown in Fig. 168. A simple gas furnace for all around work is shown in Fig. 169.

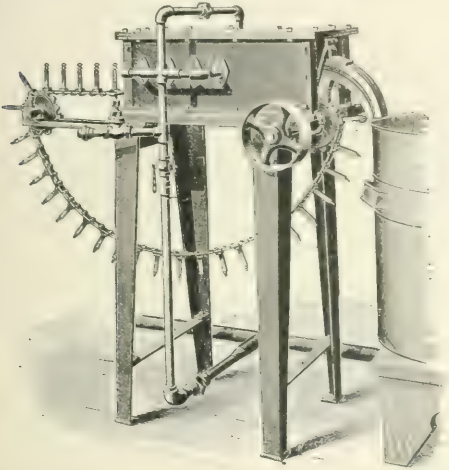


Fig. 168.

Reverberatory Furnaces. A reverberatory or air furnace is a furnace in which ore, metal or other material is exposed to the action of flame, but not to the contact of burning fuel. The flame passes over a bridge and then downward upon the material spread upon the hearth. Such furnaces are extensively used in shops where heavy work is being executed. They are also used for melting iron or other metals. For this purpose, however, they are not economical since they require about twice as much fuel as that used in the cupola for the production of good hot iron. To be effective the flame must be made to *reverberate* from the low roof of the furnace down upon the hearth and work. The form of the roof and the velocity of the currents determines the hottest part of the furnace.

A common form of reverberatory furnace is shown in Fig. 170. The whole is lined with fire brick from the top of the grates to the top of the stack. The fuel is burned in a fire box separated from the heating portion of the furnace by a low bridge wall D. Access to the grate is obtained by suitable doors both above and below. When in service, both doors are tightly closed and a strong forced draft is admitted to the ash pit. Beyond the bridge wall is the furnace proper. This usually consists of a low chamber with a level floor. Like the fire box it is completely lined with a thick wall of fire brick. Access is obtained to this chamber through a vertically sliding door. These doors are also lined with fire brick and are usually suspended from chains. These pass over pulleys, and have counter balancing weights at the other end.

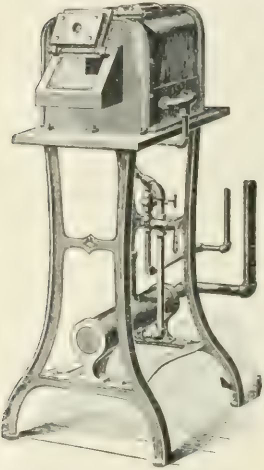


Fig. 169.

The operation of the furnace is exceedingly simple. After the fuel has been charged upon the grates, the ash pit and furnace doors are closed; the material to be heated is put upon the floor of the chamber; the doors are closed and the draft admitted to the ash pit. The thick walls which surround the furnace prevent radiation of its heat. The fire brick are, therefore, heated to incandescence and the hot gases sweep through the chamber. The flow of the gases is usually checked by a choke damper on top of the stack

The outer form of these furnaces is usually rectangular. The brick walls are tied together by stay rods to prevent bulging and the corners are protected by angle irons.

The selection of the fuel is an important matter in the operation of these furnaces. Experiments have been made with almost every kind of fuel. That now universally used is a soft bituminous coal that will not cake.

Steam or power hammers are always used in connection with these furnaces. The work is too large and heavy for manipulation by hand hammers.

An ordinary class of work done with them is the welding of slabs from small pieces of scrap. To do this a rough pine board about 12 inches wide and from 15 to 18 inches long is used. On it is neatly piled about 200 pounds of small scrap pieces. This material is then bound to the boards by wires, and the whole is placed upon the hearth of the furnace. It is allowed to remain until the whole mass is at a welding heat. When in this condition, the plastic surfaces of the pieces serve to stick them together, so that the whole mass can be handled as a single unit by the tongs. The board, of course, burns away, leaving the metal on the hearth. The metal is then lifted out and placed under the steam hammer. A few light blows serve to do the welding. After this heavier blows are struck and the mass is hammered into any shape that may be desired. Usually this first hammering gives it the form of a slab. Slabs thus made are cut up and again welded to form the metal for the final shape.

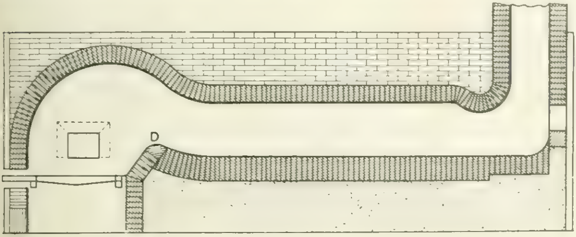


Fig. 170.

In the piling of the metal upon the board or *shingle*, as it is called, great care should be exercised. Iron and steel should not be piled together. Rusty metal should be cleaned before being put in the pile. Large air spaces between the pieces should be avoided.

The whole mass should be packed together as compactly as possible.

Bolt Headers are really upsetting machines that form the heads of bolts upon straight rods. Owing to the rapidity with which they do their work, they are invariably used for manufacturing bolts in quantities.

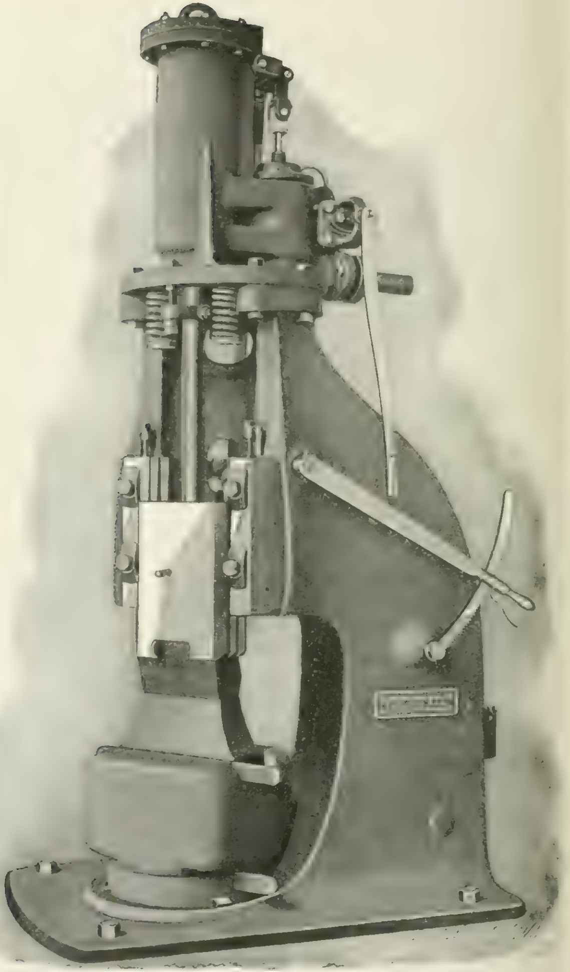
Miscellaneous Suggestions. In doing work in the blacksmith shop it must be constantly remembered that the work is larger at the time it is being manipulated than it will be when cool. Allowance must, therefore, always be made for shrinkage. As the pattern maker allows for the contraction of the molten metal to the cold casting, so the blacksmith must allow for the contraction of the hot iron or steel to the cold forging

The temperatures of iron at the several colors, are as follows:

Lowest red visible in dark	878° F.
Lowest red visible in daylight	887° F.
Dull red	1100° F.
Full red	1370° F.
Light red, scaling heat	1550° F.
Orange	1650° F.
Light orange	1725° F.
Yellow	1825° F.
Light yellow	1950° F.

This table is based on temperatures given by Messrs. Taylor and White, Transactions Am. Soc. of Mech. Engs., Vol. XXI.

From the above it will be seen that the temperature at which forgings are finished under the hammer, should be at about 900° Fahr. When these same forgings are cold their temperature will be from 60° to 70° Fahr. There is, therefore, a difference of at least 840° between the working and the finished temperature. The expansion of iron may be taken to average about .00000662 of its length for each increase of one degree Fahrenheit in its temperature. If a bar of machine steel exactly 2 feet long when cold, be heated red hot and measured, it will be found to have increased nearly ¼″ in length. Taking the temperature of the red heat as 1370° F., and that of the cold bar as 70° F., the increase in length would be 1300 × .00000662 × 24 (length in inches) = .206″. This expansion must be allowed for when measuring forgings red hot.



800-POUND BEMENT SINGLE-FRAME STEAM HAMMER.

Niles-Bement-Pond Company.

ELECTRIC WELDING DEVELOPMENT.

The art of welding iron is probably as old as the earliest production of that metal by man; in fact, the reduction of iron in the primitive forges demanded the union by welding of the reduced particles, for no true fusion could have resulted, the percentage of carbon present being too low. Until the closing years of the last century iron was the only weldable metal, if we except gold and platinum,—too expensive for common application.

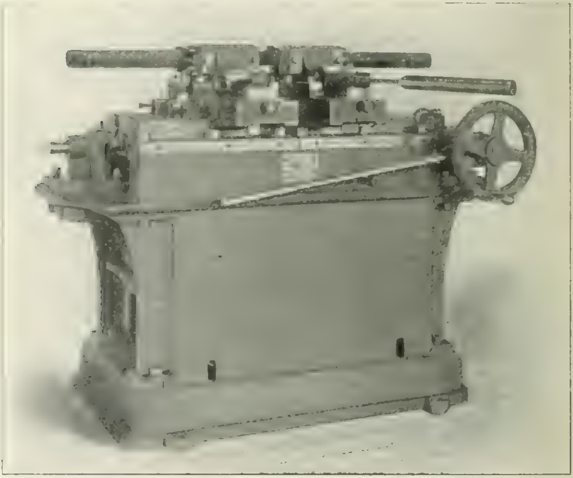
The fact that nearly pure iron, so difficult to melt, becomes quite plastic at high temperatures, while the oxide or black scale melts long before the metal itself becomes fluid, thus providing a liquid flux which is squeezed out during the process of union, accounts for the unique position which iron held until recent years. When, however, the heating effects of electric current energy, so perfectly under control, were applied to weld metals, a metal or alloy which would not weld became the exception, instead of the rule, as before. Much of the former work of the smithy fire is now accomplished by the electric welding transformer, and although many metals are easily manipulated by the electric process, iron, of course, still occupies, as ever, the principal place.

The electric weld is becoming a more and more important factor in many industries. During recent years the extension of its application has been steady, and each year has witnessed its entrance into new fields. Sometimes, indeed, new manufactures, or new ways of obtaining results have been based upon its use. The electric welds under consideration are the results of that operation of uniting two pieces of metal by what is known as the Thomson process, first brought out by the writer and rendered available in commercial practice a considerable number of years ago. The rapidity, flexibility, cleanliness, neatness, accuracy, and economy of the electric process has won for it such an important standing in the arts that many future extensions in its application are assured.

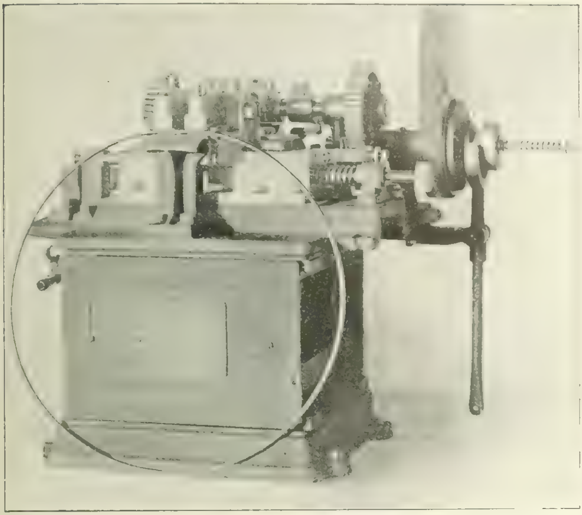
NOTE: This article by Prof. Elihu Thomson, the inventor of the system of Electric Welding, first appeared in Cassiers' Magazine, and is here reprinted by special permission.

The uniformity of the work, the control of the operation, the extreme localisation of the heat to the particular parts to be united, and the fact that the process is not limited to iron and steel, but can deal equally well with other metals, such as copper, brass, bronzes, and even lead, are characteristics of the electric welding operation.

The Electric Welder. In its simplest form, an electric welder consists of a special transformer, the primary circuit of which receives current from an electric station or dynamo generator, at a voltage usually from one hundred to five hundred times that required to make a weld. The copper secondary circuit of the transformer is generally only a single turn of very large section, so that it may develop an extremely heavy current at from two to four volts,—an electric pressure so low that it cannot give the least effect of shock, and one for which there is no difficulty in securing perfect insulation. The work pieces are held in clamps or vises, attached to or carried upon the terminals of the



ELECTRIC WELDING MACHINE FOR IRON AND STEEL PIPE.



ELECTRIC TIRE-WELDING MACHINE.

single-turn secondary circuit. The control of the clamping devices and the current switch is either manual, or, in some cases, entirely automatic. Without attempting to enumerate the many applications of electric welding in the arts, we may refer to a few examples.

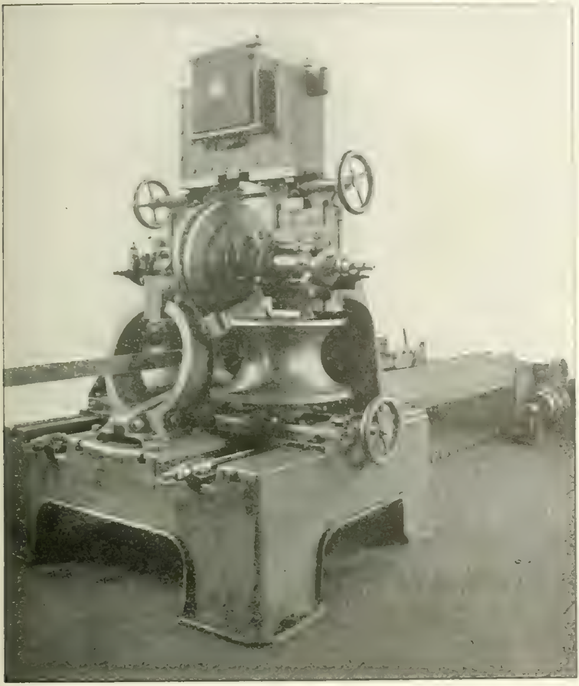
Applications. In the waggon and carriage industry the process is applied in the production of tires of all sections, axles, hub, spoke and sand bands, fifth wheels, shifting rails, steps, shaft iron, etc., while it has found a large use in the welding into continuous strips or bands of the wires inclosed in rubber tires for holding them in place. The larger part of the dash-frames used in carriages in the United States are now probably made by electric welding, while iron and steel agricultural wheels are built up, or have their parts united, by electric welds.

To enumerate the many applications to the bicycle industry would be almost to catalogue most of the metal parts of this useful machine. It must be borne in mind, too, that a welding machine, slightly modified, is equally applicable for locally heating parts in electric brazing or hard soldering, for upsetting, and for bending or shaping. Bicycle crank hangers, pedals, seat-posts, fork and fork ends, frames and brake parts thus become products in which the welding transformer has its part. It has found a useful field also in tool manufacture, such as drills, reamers, taps, band and circular saws, drawing knives, carpenter's squares, printer's chases, etc., etc., and electric welding has a closely related use in the production of machine parts. Cam shafts and crankshafts are made from drop forgings welded together, teeth are inserted into gear wheels, and teeth are welded to saw bodies, including stone saws. Such things as inking rolls in printing machines and fallers for looms are additional examples.

In the wire industry the part played by electric welding is already quite important, and becomes steadily more so. Besides the mere simple joining of wires of iron, steel or copper into long lengths, the welding of wire or strip into hoops for barrels, tubs, pails, etc., is supplanting the older forms. Numerous machines are in operation turning out electrically-welded wire fence, much as a loom turns out cloth. In pipe bending and coiling, as in uniting ordinary lengths of pipe into very long lengths without screw joints, the electric weld has a special adaptability. Hundreds of miles of street railway rails have been welded into continuous lengths and now exist in many cities. Where rails are bonded only, the electric welder assists in the production of brazed or welded bonds.

It is a wide range between buckles, typewriter bars and umbrella rods to the local annealing of armour plates on warships, but the electric welder covers that range. It is no wider, however, than that from fine wires of a diameter of one-fiftieth of an inch up to heavy steel wire for the armour of submarine cables, and again up to street railway rail joints.

In recent years, elaborate machinery, for the actual production on a large scale of steel tubing from flat stock or skelp by the progressive welding of a longitudinal seam, has been put into operation. The long strip, or skelp, is rolled up so that its edges meet. In this condition it enters between the welding rolls, which



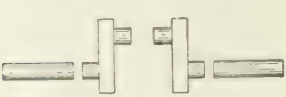
WELDING MACHINE FOR LARGE TUBES OR SHELLS UP TO 16 INCHES IN DIAMETER.

pass the heating current locally across the edges to weld them, and the operation is progressive from one end of the pipe to the other as it is fed into the machine. The result is a pipe of which the walls are of even thickness and the diameter uniform. This pipe can be afterward drawn, if needed, to the exact size desired. Very thin pipe can be made of steel, the longitudinal seam or weld in which is a delicate bead along the length, a beautiful product, for the extreme localisation of the heat has allowed preservation of surface and finish of the metal outside the joint. Taper tubes, such as are used for bicycle front forks and the like, are easily made.

A similar machine for large work has lately been constructed, and by its use large diameter tubes or shells, up to 16 inches in diameter, are produced from sheet steel or iron. The accompanying illustration shows such a machine ready for operation. The welding transformer is at the top of the machine, and the secondary circuit has for its terminals two copper rolls inclined to each other on two nearly horizontal shafts adjustable in position over the work. Below are the guide rolls, one on each side on vertical shafts, and between these the shell to be welded passes with its meeting edges uppermost and in contact with the copper contact rolls. As the metal shell passes along under these rolls the joint is progressively heated by the welding current crossing it, and the weld is finished by the side pressure of the guiding rolls. The process, as well as the resulting welded product, is unique.

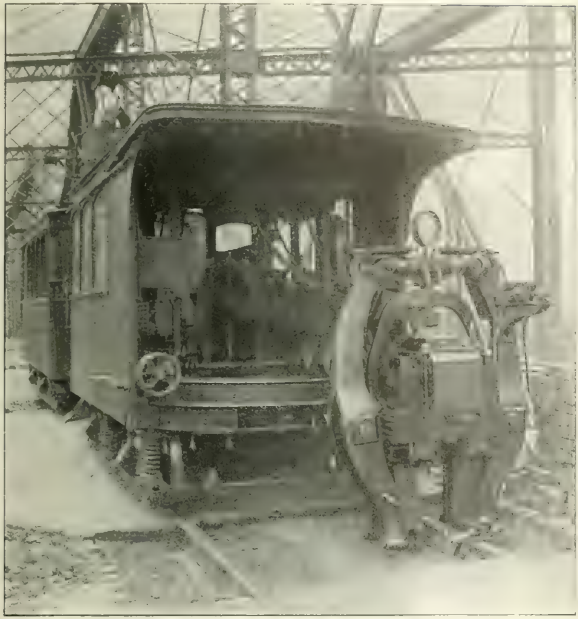
For a considerable time past, welding machines have been applied to the production of bands or tires from stock of varying width, thickness, and sectional form. More recently the practice of welding plain bands or cylindrical rings, and afterwards rolling them with the form of section desired, has been largely adopted; such as, for example, in the production of automobile wheel rims, bands for roving cans, stove rings, etc.

Very different from this is the formation of crankshafts, now demanded in great numbers for engines of automobiles. These are made from drop forgings and round shaft stock by uniting the pieces, as in the annexed sketch, and afterwards lightly machining and finishing the approximately correct shaft, as produced by welding.



Besides the banding of wire or strip of such comparatively frail containing vessels as barrels or pails, the electric weld finds application in the forming and capping of metal vessels for withstanding high pressures, such as soda-water cylinders, carbonic acid reservoirs, and steel bottles for nitrous oxide gas.

One of the most interesting of the more recent applications is that of welding hollow steel handles on cutlery, such as table



ELECTRIC RAIL WELDING ON STREET RAILWAYS.

knives and forks. The operation is remarkable for the celerity and neatness of the work, the articles being finished by silver-plating and polishing, as usual. The hollow handle is drawn from thin steel, and united to the knife blade or to the fork, as the case may be, in a special welding machine, there being no brazing or other operation of joint-forming required. There is, indeed, no limit to the delicacy of the work which may be undertaken, provided only the welding apparatus is equally refined.

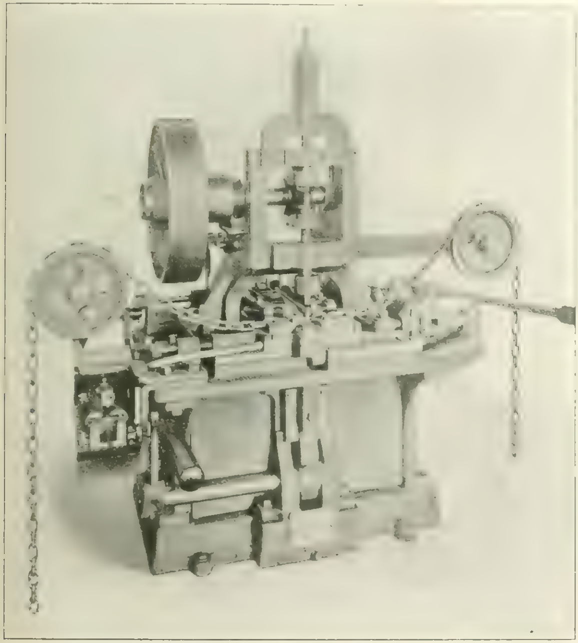
Adjustments. In the simpler types of electric welders, especially where the machine is designed to do a variety of work, perhaps of different forms or sizes of pieces, or both, the adjustments are usually manual; that is to say, the operations of clamping the pieces and applying the electric current and mechanical pressure are each controlled by the operator. In other cases, such as in the welding of copper or aluminium wire, the machine is, at least in part, automatic. The pressure is automatically applied and the welding current is cut off automatically upon the completion of the joint; the placing of the pieces in the clamps and the switching on of the current is in this case, manually performed.

In other, more completely automatic, types, particularly adapted for rapid repetition of the same operation on identical pieces, the machine runs continuously, and its sequence of actions is definitely determined by the construction. In such cases a source of power, as by a belt, drives the machine, the movement so imparted having the effect of clamping the pieces as they are fed to the machine, putting on the current, applying the pressure, cutting off the current and releasing the pieces.

The mechanism which has been developed for these purposes displays, in many instances, much ingenuity. In these machines the duty of the attendant is limited to the mere placing of the pieces between the clamping jaws, just before they are clamped, and the work is characterised by rapidity and by uniformity of the results.

More completely automatic still are machines for the production of wire fencing and for the consecutive welding of the links of chains. In these the operation, once started, goes on uninterruptedly so long as the work holds out, or until the stock undergoing operation is exhausted. In the fence machines, of which fifteen are now in existence, galvanised iron wires are fed from reels parallel to one another, at distances apart depending on the mesh desired. These may correspond to the warp in weaving. Transversely to these, and at intervals corresponding to the mesh selected, are fed wires, cut from a reel, which transverse wires are the verticals in the finished fence itself and correspond to the weft in weaving. A series of small welders are automatically brought into operation to weld each transverse wire to the longitudinals where the two cross. This done, the web so formed moves forward, the operation repeats itself, and so on continuously. The welding is, in this case, practically instantaneous, and all of the movements of the machine are entirely automatic.

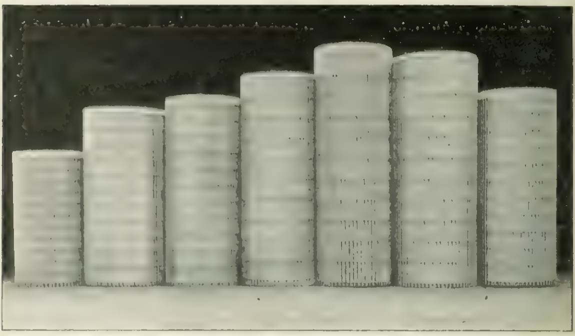
In this way it is possible for a single machine to turn out many thousands of feet of fencing per day with a width of mesh from 2 or 3 inches up. Less wire is used than where the joints are made by twists or loops, and the stability or fixedness of position of such joints as are made is much more assured.



ELECTRIC CHAIN-WELDING MACHINE.

Joints. While in most cases of electric welding the joint forms what is known as a butt weld, with a burr or extension of metal at the joint, which, according to conditions, is either allowed to remain or is forged down or dressed off, there is no difficulty in making lap welds electrically, and some of the recent work of the electric welder is of that character. While, too, the usual welding concerns pieces of the same metal, as iron to iron, steel to steel, or copper to copper, combination welds of different metals are made with facility in many cases, as when brass and iron are united.

In the working of high-carbon steels the usual precautions to prevent burning or injury to the metal are, of course, required; but, on account of the delicacy of heat control, they are more easily adopted.



ROLLS OF ELECTRICALLY-WELDED WIRE FENCE.

Quite recently automatic chain welders have been put into use, and electrically-welded chain work will probably soon attain an importance not second to the other principal applications which have been briefly described.

REVIEW QUESTIONS.

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for College, Civil Service, or Engineer's License. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

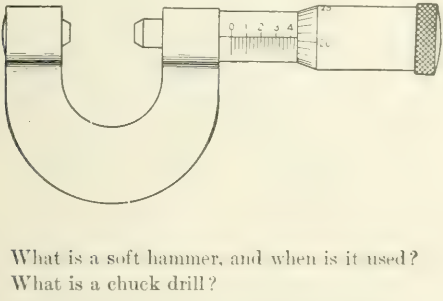
MACHINE SHOP WORK.

PART I

1. What are limit gauges?

2. When are calipers used? and how are they set?

3. If there are 40 threads per inch on the micrometer screw, what is the reading of this micrometer?



4. What is a soft hammer, and when is it used?

5. What is a chuck drill?

6. What methods are used for cleaning a file?

7. How should a file be held for fine filing?

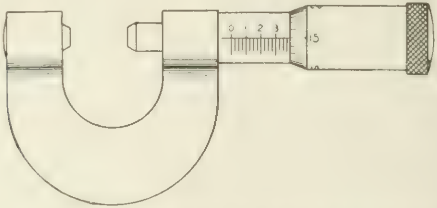
8. Describe the surface gauge.

9. Describe the micrometer caliper.

10. Describe two common forms of chisel, and state under what conditions they are used.

11. Why is not the cutting surface of a file perfectly flat?

12. Give the reading of the micrometer caliper when in the position shown.

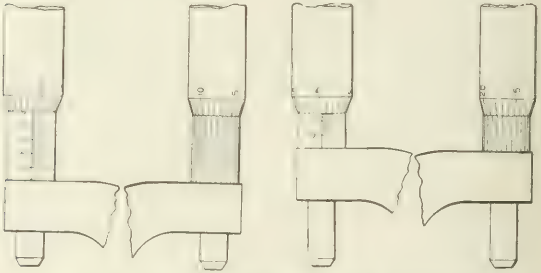


13. What methods are used for holding a file for filing large surfaces?

14. Describe the twist drill.

15. What is a vernier?

16. What is the reading of the vernier micrometer caliper when in the positions shown?



17. What is the result when the lips of the twist drill are of unequal length?

18. When are reamers used?

19. How much less should the diameter of the drilled hole be than finish size if a reamer is to be used?

20. Explain the methods of cutting screw threads with a die.

21. What advantage has an adjustable reamer over a solid reamer?

REVIEW QUESTIONS

ON THE SUBJECT OF

MACHINE SHOP WORK.

PART II

---

1. What is a mandrel?

2. Describe the rise-and-fall rest.

3. How long will it take to turn a chip 18 inches on a shaft 24 inches long and 3¼ inches in diameter?

Assume cutting speed 20 feet per minute.

Assume feed $\frac{1}{50}$ inch per revolution.

4. Describe the process of making a taper fit.

5. The lead screw has a pitch of ¼ inch. What is the ratio of gears to be used to cut a screw with 18 threads per inch?

6. Describe the process of bringing the countersink back to center.

7. For what purpose is the back gear of a lathe?

8. Describe some method of adjusting pieces to center.

9. Describe the shapes, and state the uses of the following lathe tools: Diamond point, side or facing tool, parting tool, and square-nosed tool.

10. Why are lubricants used in turning?

11. Describe the method for finding the clearance for a tool for cutting square threads.

12. On account of not having the proper gears at hand compound gears must be used. The lead screw has 4 threads per inch, and a screw having 9 threads per inch is to be cut. The gears chosen for drivers are of 24 teeth on the spindle gear and 30 on the intermediate. What gear should be used for the intermediate driven if the screw gear has 60 teeth?

13. Describe the U.S. Standard thread.

14. Describe the steady rest.

15. How would you adjust a piece to center if the hole must be run true?

16. Why should a boring tool have more clearance than a turning tool? Explain with sketch.

17. Explain the method of turning a taper by setting the tailstock over.

18. In what direction does the carriage run when cutting a right-hand thread?

19. A screw of 14 threads is to be cut in a lathe having a lead screw of 3 threads per inch. Compound gears are to be used. The gears available have 20, 30, 40, 50, 60, 70, and 80 teeth. What ones are to be used and where?

20. How is motion transmitted from the cone pulley of a drill press to the drill?

21. How is motion transmitted from the spindle to the lead screw?

22. Describe clearance and rake as applied to a lathe tool. Give approximate values in degrees for cutting steel.

23. Should a tool for turning brass have rake? Why?

24. The end of a piston rod is to be turned tapering. The piston rod is 28 inches long; the tapered portion is to be 3 inches long. The diameters of the taper are to be 2¼ inches and 2⅝ inches. How much must the tail block be set over?

25. Suppose the lead screw of a lathe has 4 threads per inch and we wish to cut 11 threads per inch. The gear on the spindle has 20 teeth. What gear should be chosen for the lead screw?

26. What is a universal radial drill?

27. In what ways is a twist drill preferable to a flat drill? How is the drill made to turn with the spindle?

28. Describe the universal chuck.

29. Why should not a tool be set too high?

30. How long will it take to turn a chip from a shaft 37 inches long 5½ inches in diameter?

Assume cutting speed 23 feet per minute.

Assume feed of $\frac{1}{32}$ inch per revolution.

REVIEW QUESTIONS

ON THE SUBJECT OF

MACHINE SHOP WORK.

PART III

---

1. What is interchangeable work?

2. Explain the method of grinding valves.

3. What is pickling?

4. In what direction relative to the motion of the cutter should the work on a milling machine be fed?

5. What is the difference between pening and bending?

6. What is the difference in the rates of revolution given for surface milling of cast iron, with a surface milling cutter $3\frac{1}{2}$ inches in diameter, according to Addy's rule and the Brown & Sharpe table?

7. What are the principal uses of the grinding-machine?

8. What is a surface plate? Describe the process of making.

9. Describe the hydrostatic level.

10. What is the safe rate of revolution of an emery wheel 5 inches in diameter, if its surface speed is not to exceed 4,000 feet per minute?

11. A surface of cast iron is to be finished in one cut on the milling machine. The casting is 8 inches long and 5 inches wide. The milling cutter has a diameter of 3 inches and the width of 2 inches. How long will it take to do the work? Assume feed of $2\frac{1}{2}$ inches.

12. What is a lap? Of what metal should it be made?

13. How may a permanent joint be made?

14. Describe in a general way the setting of a machine.

15. What should be the diameter of a piece as it comes from a lathe if it is to be ground to a diameter of 4 inches?

16. According to Addy, how long would it take to mill a cast iron surface 18 inches long, and 16 inches wide, with a milling cutter 6 inches in diameter and 3 inches wide.

17. How is a surface prepared for laying out work?

18. How are temporary joints made?

19. How many horse-power may be safely transmitted by a single belt 8 inches wide, running over a 36-inch pulley which makes 175 revolutions per minute?

20. State some of the uses of the milling machine.

21. How are case-hardened pieces usually finished?

22. What tools are used for laying out work? Explain the function of each.

23. Why should a lathe or planer tool work beneath the surface of a casting?

24. How may the power transmitted by the belt in Question 19 be increased to 32 horse-power?

25. According to Addy's rule, what should be the speed of a milling cutter 8 inches in diameter when working in cast iron?

26. Which is preferable for high polish, new or old emery cloth? Why?

27. If the feed is 1.5 inches per minute, how long will it take to cut a groove 2 inches wide, 4 feet long, $\frac{1}{4}$ inch deep? The material is soft machinery steel, and the milling cutter is $2\frac{1}{4}$ inches in diameter and $1\frac{1}{4}$ inches wide.

28. Should work be calipered while at rest or while in motion?

REVIEW QUESTIONS

ON THE SUBJECT OF

FORGING

1. Make a sketch and show all dimensions of a hoisting hook for a load of 2,000 lbs.

2. What is the essential difference between tool steel and wrought iron?

3. What is shrinking?

4. What three materials are commonly used in forge work?

5. Give two methods of measuring the amount of stock required to make a scroll.

6. How much would the crank shaft shown in Fig. 82 weigh, before any machine work was done on it, if $\frac{1}{4}''$ be allowed for finish on all surfaces where called for?

7. How is a lead bath used, and what is the advantage in tempering?

8. What length of stock, $\frac{1}{2}''$ in diameter, is required to make a ring 3″ inside diameter? No allowance for welding.

9. What is meant by the term "allowance for finish"?

10. What is annealing?

11. How does brazing differ from welding?

12. What is the tuyere?

13. If two plates are to be riveted together as tightly as possible, should heavy or light blows be used?

14. What is meant by "the hardening heat?"

15. Make a sketch showing what dimensions the forging shown in Fig. 78 would have if $\frac{1}{4}''$ finish were allowed all over.

16. Of what does welding consist?

17. What precautions must be taken when forging a round bar to a point?

18. Three pieces of tool steel are heated to the hardening heat; the first is cooled in water, the second in oil, and the third is allowed to cool in the air. What will be the relative hardness? Why?

19. How are tongs fitted to work?

20. Make a sketch and show all dimensions of a hexagonal head bolt ¾" x 8".

21. How is the final hardness of steel affected by the rate of cooling?

22. If a tap is broken off in a piece of work, the work is wanted in a hurry, and it is necessary to anneal the piece, how can the annealing be done?

23. What is brazing?

24. How much would an anvil marked 3 - 2 - 10 weigh?

25. Why are scarfs used in welding?

26. Why are springs hardened and tempered in oil?

27. Why is borax a better flux than sand?

28. What are the characteristics of a good forge coal?

29. What determines the size of the grain in hardened steel?

30. What is the down draft system?

31. What is meant by scarfing?

32. What is meant by clearance on lathe tools?

33. What is a flux, and why is it used in welding?

34. How are steam hammers rated?

35. Why should the ends of pieces to be welded, be upset?

36. (a) What do you understand to be meant by an oxidizing fire? (b) What do you understand to be meant by a reducing fire?

37. In making an S wrench, which is preferable; to forge the jaws separately and then weld on the handle, or to cut the jaws from a solid piece of metal and draw down the material between them to the proper size for the handle?

38. Explain the method of making a ladle shank in such a way that no welds are necessary in its construction.

39. Describe with sketches the so-called commercial method of forging a crank shaft.

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